Saskatchewan
Energy and Mines

Saskatchewan
Geological Survey

Miscellaneous Report 86-4

# Summary of Investigations 1986, Saskatchewan Geological Survey

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ISSN 0228 5657
Printed by Saskatchewan Government Printing Company

## Foreword

The Summary of Investigations 1986 includes papers on Saskatchewan geological projects performed in the current year by staff of the Geological Survey, as well as submissions from the Geological Survey of Canada, the Saskatchewan Research Council, the Universities of Regina and Saskatchewan, and Kansas University.

Most of the projects and studies reported on for the Precambrian Shield reflect the stimulus of Sector A of the Canada-Saskatchewan Mineral Development Agreement 1984-89, now in its third year of implementation. This is a co-operative program, concentrated, though not exclusively, on the precious metalliferous region bounded by a line joining La Ronge, Flin Flon and Reindeer Lake. The program is work-shared with the Geological Survey of Canada and extends linkages of the other institutions through working agreements. These institutions, thanks to their independent funding and professional resources, serve to amplify and invigorate the geological effort of the Survey, especially in the specialties and expertise not available in house.

A special transfer of funds by Saskatchewan Energy and Mines to the budget of the Survey made possible a 16 percent expansion of the northern projects. This sub-budget is referred to in the text as the Geoscientific Expansion Program.

The other Sections of the Mineral Development Agreement are allocated to technology and market development of the industrial minerals. These funds reside with Energy, Mines and Resources Canada. Projects in these sections are designed to deal with, in conjunction with the potash industry, problems related to the ore processing and the mining environment; and with the appropriate industry agents, kaolin and building stone.

Projects on the subsurface strata of southern Saskatchewan, especially with respect to petroleum and natural gas, have been resuscitated, and reflect the need to delineate prospects for future exploration and development now, during the current industry lull. Likewise, in house, and by contract with the University of Saskatchewan, studies of strata contingent to safety of the potash mining environment have been stepped up, in view of water inflow problems at several of the mines.

Whereas petroleum and potash industrial activities are weathering heavy seas, gold is up on the crests. However, it is the understated uranium industry, ballasted with rich reserves, low-cost high production and an Athabasca Basin exploration framework still in the early stages, which is the consistent performer. The Saskatchewan Geological Survey attempts to serve these industries with the right mix of projects and expertise. However, it is a big ocean.

All contributions to this year's program and the Summary of Investigations are herewith gratefully acknowledged.

J. E. Christopher
Director
Saskatchewan Geological Survey

October, 1986

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**Note: Asterisked reports have an accompanying map. A list of accompanying map titles can be found on the inside front cover of the map package.**

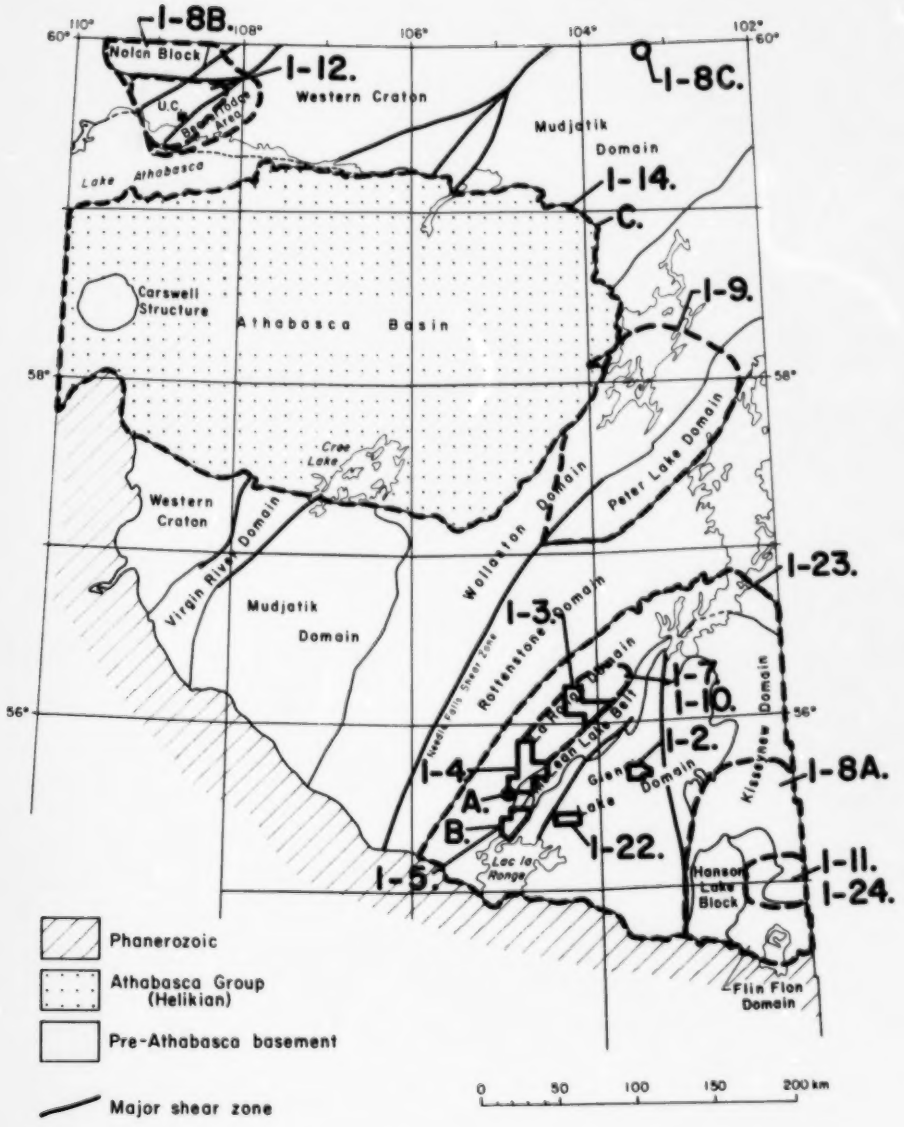


**Figure 1 - Location of projects or reports in hand. Numbers or letters on map refer to ERDA numbers or letters listed opposite.**

## Highlights of the Geoscience Program

by R. Macdonald and T.I.I. Sibbald

The Summary of Investigations (1986) includes more geoscience projects than in recent years. This reflects not only the continuation of the five-year Canada-Saskatchewan Agreement on Mineral Development under the Economic and Regional Development Agreement 1984-89 (ERDA), now in its third year, but also the addition this year of the provincial Geoscience Expansion Program (GEP) and the larger number of supporting reports from "associated researchers" in the geoscience field.

ERDA comprises an agreement by the province and the federal government to mount individual but coordinated geoscience programs on a 50:50 parallel delivery basis. The provincial component, mainly under the "Gold Belt Geology" program, is primarily concerned with field-based projects aimed at stimulating and assisting the mineral exploration industry in its search for gold and precious metals.

An initiative has also been taken into the area of industrial minerals, notably clay and building stone research, of which the former is reported here.

The federal part of the program, undertaken by the Geological Survey of Canada, mainly comprises regional airborne magnetic gradiometer and regional lake sediment surveys. The gradiometer surveys are scheduled to cover parts of the Central La Ronge Metavolcanic Belt and the area lying west of Flin Flon along the Shield edge as far as Hanson Lake. The reconnaissance lake sediment surveys have completed coverage of the whole of the Saskatchewan Shield to as far north as latitude 58° 30'N. The GSC is also providing ground geological studies which include a four-year mapping review of the Kisseynew Gneisses, as well as mineral deposit studies at selected sites. A number of progress reports on these projects are included in this volume.

| ERDA No. | Proj. No. | Area/ Short Title | Project Leader | Notes |
|---|---|---|---|---|
| **Gold Belt Geology Projects:** | | | | |
| 1-2 | 8622 | Bedrock Mapping, Laonil Lake Area | G.D. Delaney | 1 |
| 1-3 | 8611 | Bedrock Mapping, Windrum Lake Area | C.T. Harper | 1 |
| 1-4 | 8612 | Bedrock Mapping, Esmay Lake Area | D.J. Thomas | 1 |
| 1-5A | 8606A | Bedrock Mapping, Sulphide Lake Area | T.I.I. Sibbald | 1 |
| 1-5B | 8606B | Bedrock Mapping, Hebden Lake Area | W.L. Slimmon | 1 |
| 1-5C | 8609A | Bedrock Mapping Mackay Lake South | M.W. Thomas | 1 |
| 1-5D | 8624A | Bedrock Mapping Mackay Lake North | J.F. Lewry | 1 |
| 1-7 | 8608 | Geochronology: Rb-Sr | K. Bell and M. Bikerman | 1,3 |
| 1-8A | 8607A | Geochronology: U-Pb Zircon Trans-Hudson Orogen | M.E. Bickford et al. | 1,4 |
| 1-8B | 8607B | Geochronology: U-Pb Zircon Uranium City Region | W.R. Van Schmus et al. | 4 |
| 1-8C | 8607C | Geochronology: U-Pb Zircon Ennadai Group | J.R. Chiarenzelli et al. | 4 |
| 1-9 | 8625 | Isotope Geology: Nd-Sm | K. Collerson | 1,3 |
| 1-10 | 8621 | Geochemistry: Central Metavolcanic Belt | B.R. Watters | 1,3 |
| 1-11 | 8602 | Geochemistry: Kisseynew Metallotect Geochemistry | G.R. Parslow | 1,3 |
| 1-12 | 8603 | Martin Sedimentology | P.K. Mazimhaka and H. Hendry | 1,3 |
| 1-14 | - | Athabasca Basin Report | P. Ramaekers | 3 |
| 1-18 | 8605 | Mineralized Core Collection | A.J. Gracie | 1,2 |
| 1-22 | 8624B | Nistowiak Tectonic Studies | J.R. Chiarenzelli | 1,4 |
| 1-23 | 8609B | Gold Anomaly Follow Up | M.W. Thomas | 1,3 |
| 1-24 | 8614 | Kisseynew Metallogeny | J.G. Pearson | 1 |
| **Other Northern Studies:** | | | | |
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| | B. | Quaternary Geology: Sulphide-Hebden Lakes | J.E. Campbell | 1,5 |
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1 Field component in 1986
2 Project covering wide area (not shown on map)
3 Contracted project in 1986
4 Joint venture project with SEM in 1986
5 Externally contributed report

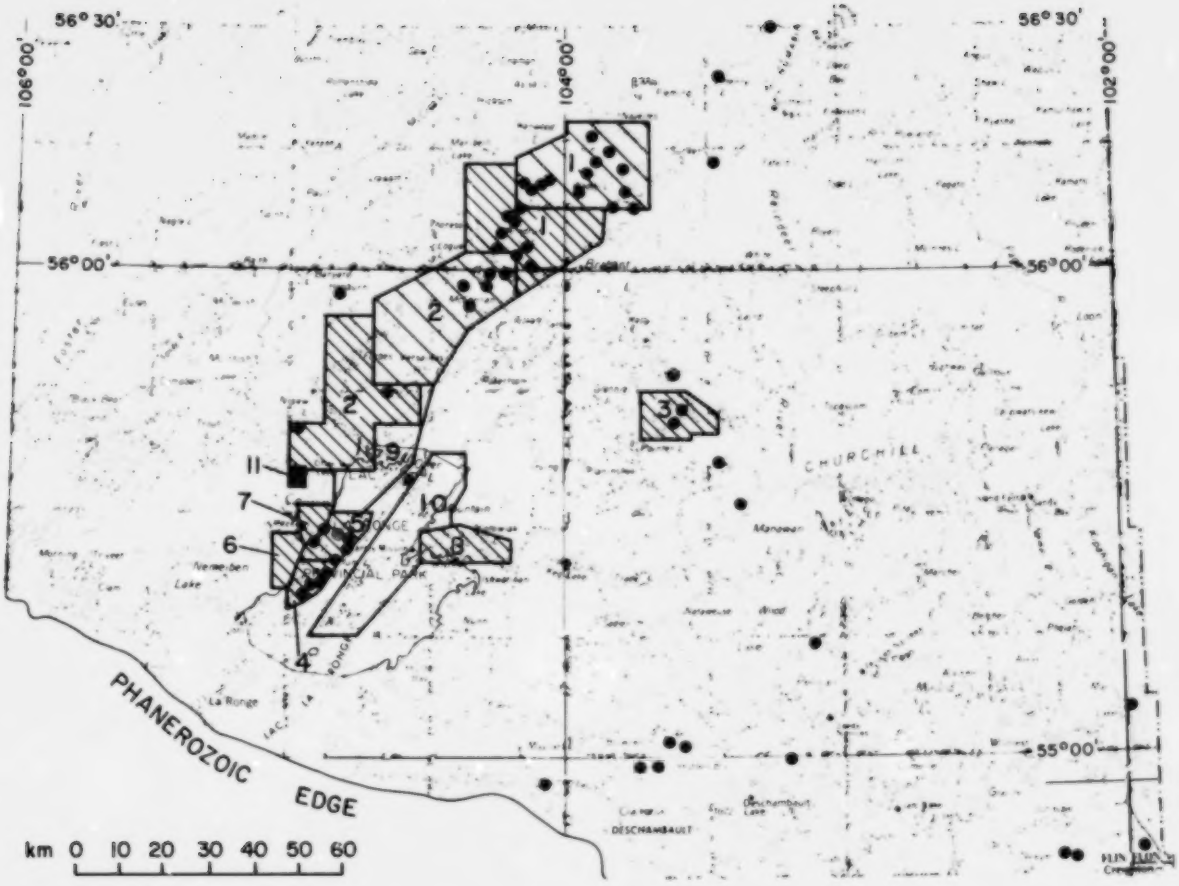


Figure 2 - Progress of bedrock remapping at 1:20,000 scale in the La Ronge and Glennie Domains. Dots represent approximate locations of known gold occurrences.

Gold Belt Geology Program:

Remapping in 1984 and 1985

Remapping in 1986 (this report)

Other:

Remapping in 1981

Remapping in 1986 (this report)

Geologists:

1 C.T. Harper; 2 D.J. Thomas; 3 G.D. Delaney; 4 T.I.I. Sibbald; 5 W.L. Slimmon; 6 M.W. Thomas; 7 J.F. Lewry; 8 J.R. Chiarenzelli; 9 A. Abraham; 10 J.F. Lewry (1981).

## Gold Belt Geology and Geoscience Expansion Programs

The provincial Geoscience Expansion Program (GEP) was set up this year in order to boost bedrock mapping in the current areas of gold exploration. The extra funds permitted the mounting of a new remapping project in the Laonil Lake area, and an acceleration to the mapping coverage of the Central Metavolcanic Belt (CMB). As a result, bedrock remapping of the CMB at 1:20,000 scale has now been extended as far south as Missinipe (Figs. 1 and 2).

### Central Metavolcanic Belt Mapping:

The Windrum Lake area (C.T. Harper) is one of the least deformed parts of the CMB. Volcanics are well represented as dominantly pristine mafic flows and pyroclastics. A metarhyolite has been discovered which contains lemon-sized lithophysae, and elsewhere chiastolite crystals up to 14 cm long were found in meta-argillite. The Brindson Lake Pluton is a complex multiphase intrusion, the eastern side of which is separated from the

adjoining Payn Creek Pluton by a major shear zone. A highly gossanous package of pyrrhotitic calcareous metasediments of the Crew Lake Belt flanks the west side of the Kenwood Lake Pluton.

Exploration models - The most significant gold occurrence in the Windrum Lake area is the Jojay deposit, where gold and sulphides are hosted in a quartz stringer stockwork. Similar mineralization occurs elsewhere along the same trend. C.T. Harper has also targetted several other favourable situations based upon the occurrence of quartz veins/shear zones, intrusion breccias, sulphide- bearing diorite sills, and local iron formation. In addition he has pointed out the potential for 'Komis-style' sulphide-associated mineralization around the Windrum Lake and Bryenton Lake Stocks. The gossanous rocks west of the Kenwood Pluton may also be favourable targets.

This year's remapping in the Esmay Lake area (D.J. Thomas) at the southern end of the CMB has revealed an incremental decrease southwards in the proportion of volcanic rocks, together with an increase in the proportion of metasediments and plutonic rocks. This is coupled with a general rise in metamorphic grade and penetrative deformation. The Bernaski Bay Pluton has a major gneissic and migmatitic component, suggestive of a deeper crustal level and possible basement involvement.

Exploration models - A number of favourable locations for gold mineralization are suggested. Potential environments for stratabound gold include the transition between the predominantly volcanic rocks in the north and the volcanic-sedimentary assemblages in the south, and the transition between the sedimentary Crew Lake Belt and the CMB. Other regional targets are various combinations of shear zones with carbonate-filled breccia, tension-gash quartz veins, disseminated sulphides, mafic dykes and porphyries, particularly where these cut the more competent plutonic rocks. The major McLennan Lake Shear Zone itself is a regional target, particularly where attenuated between more competent rock masses.

Sulphide - MacKay - Hebden Lakes Area Mapping:

The remapping of the area around Sulphide, MacKay and Hebden Lakes was divided between four geologists working for part of the season (Figs. 1 and 2). J.F. Lewry (University of Regina) in the MacKay Lake North area has identified a volcanic assemblage (extension of the CMB) which is overlain, at a landscape unconformity, by an arkosic assemblage (extension of the McLennan Group) which incorporates boulders of the volcanics and associated granite.

M.W. Thomas (Regina consultant), in a report on the MacKay Lake South area, has traced a zone of generally garnet-free 'metagreywackes' of the Crew Lake Belt which are overlain with no stratigraphic break by predominantly metavolcaniclastic rocks of the extension of the CMB - an inverse sequence to that postulated further north in the belts. Despite relatively high metamorphic grades, regional pervasive deformation, refolding and local anatexis, Bouma structures have been observed and are the basis for Thomas's way up criteria.

W.L. Slimmon, working east of Lewry and M.W. Thomas, in the Hebden Lake area, has traced the closure of the (presumably McLennan Group) meta-arkoses mapped by Lewry, and confirms the presence of meta-arkoses northeast of Hebden Lake which were previously mapped as granite. Mixed hornblendic supracrustal rocks are probably extensions of the CMB.

T.I.I. Sibbald, working in the Sulphide Lake area itself, has identified a succession comprising 1) pillowed mafic metavolcanics at the base, 2) a heterogeneous assemblage of predominant felsic to intermediate metavolcaniclastics and metasediments, and 3) metagreywackes. To the immediate west, in the MacKay Lake South area, the pillowed mafic flow rocks overlie volcaniclastic rocks and garnet-free metagreywackes. The geological map on this area is expected to be published later this winter.

Exploration Models - In the Sulphide Lake area gold mineralization occurs largely in the heterogeneous assemblage in several forms: a) stratabound and related to sedimentation hiatuses marked by carbonaceous argillites (Sulphide Lake area), b) shear zone-controlled in metadiorite- gabbro bodies (Pap Lake area), and c) in dilational veins related to late folding. Other regional exploration targets suggested in the Sulphide - Mackay - Bebden Lakes area include quartz-veined shears in diorite-gabbro of the Little Deer Pluton, shears associated with gossans in the linear belt lying generally along Freestone Lake, and skarn-type mineralization at Five Fingers Lake.

Laonil Lake Area Mapping:

G.D. Delaney, in the first detailed mapping of the gold-bearing Laonil Lake area, has identified an assemblage of multiphase ultramafic to intermediate intrusives (the Laonil Lake Intrusive Complex), and has produced a more detailed map of the contiguous supracrustal rocks.

Exploration Model - The gold at the Seabee deposit is hosted in quartz-tourmaline veins lying in shear zones within the intrusive complex. This exploration model may be applicable to other sheared intrusive complex rocks rimming the Eyahpaise Lake Pluton and elsewhere.

Geochronology and Lithogeochemistry:

Geochronological studies have continued to be contracted or joint-ventured with university departments during 1986.

Rb-Sr and K-Ar Studies - Although not reported here, K. Bell and M. Bikerman, of Carleton University and the University of Pittsburgh respectively, collected this summer from plutons and volcanics in the CMB in an attempt to date some of the later events in the belt, particularly those associated with the gold mineralization. Ar-Ar and Nd methods may also be employed.

U-Pb zircon Studies - The joint venture with Kansas University (M.E. Bickford and W.R. Van Schmus) is now bearing much fruit. Three reports are included here which summarize results to date, and list the samples collected this summer principally from the Flin Flon - Kisseynew - Hanson Lake Block area.

Notable new results during the year may be summarized:

| | |
|---|---|
| Central Metavolcanic Belt (consolidated results): | |
| Metavolcanics | ca. 1876-1880 Ma |
| Plutons | ca. 1834-1866 Ma |
| Beaverlodge area: | |
| Lodge/Elliot Bay Granites | ca. 3014-3072 Ma |
| Mackintosh/Athona Granites | ca. 2327-2356 Ma |
| Gunnar Granite | ca. 2181 Ma |
| Box Granite | ca. 1994 Ma |
| Nolan Block | ca. 2600 Ma |
| Ennadai Group | ca. 2680 Ma |
| Peter Lake Domain | ca. 2556-2582 Ma |
| | ca. 1865 Ma |

Nd Studies. - K.D. Collerson, who has now moved to the University of California, Santa Cruz campus, is this year engaged on work in the Wollaston and Peter Lake Domains. We hope, amongst other things, that a sample from fragmental felsic volcanics will provide a date for the Wollaston Group.

Lithogeochemical Studies - B.R. Watters (University of Regina) continues work on the geochemistry of the CMB, this year turning more attention to the plutons. His report also includes Rb-Sr isochron dates from the Star Lake and Bervin Lake plutons which accord well, at about 1850 Ma, with the U-Pb zircon dates from the CMB.

G.R. Parslow (University of Regina) continued lithogeochemical investigations of the "Kisseynew Metallotect" with studies in the Manson Bay area of Wildnest Lake and at Stump and Keep Lakes to the north. On a regional scale, the essentially volcanogenic "metallotect" rocks are only slightly enriched in gold and copper, possibly of syngenetic origin. Significant gold enrichments, on the other hand, are unrelated to copper and are possibly epigenetic (tectonically controlled). A lithogeochemical investigation of gold-bearing and barren shear zones was also undertaken in the Star Lake area.

Metallogenic Studies:

J.G. Pearson initiated studies of base and precious metals deposits in the Kisseynew Domain and Kisseynew Domain - Flin Flon Domain transition zone by mapping two prospects in detail. The Schotts Lake copper-zinc prospect shows many features typical of exhalative massive sulphide deposits. The Dolly gold prospect at Mari Lake is characterized by dilational gold-quartz veins emplaced within a shear zone, possibly related to a phase of late granite intrusion.

M.W. Thomas (Regina consultant) resampled selected gold and/or base metal anomalies in the Kisseynew Domain and Hanson Lake Block which had been identified in regional lake sediment surveys conducted by the GSC in the southeastern part of the Shield in 1974 and 1985. Correlation between gold data of the original survey and this follow-up survey is poor, and the levels of gold identified were considered too low to justify further work.

Sedimentology of the Martin Group:

The report by P.K. Mazimhaka and H.E. Hendry (University of Saskatchewan) deals largely with the provenance of boulders in the Martin Group. The final report on this project is expected in the Spring of 1987.

Other Studies

I. Graham et al. have contributed a report on an investigation of the Bassett Lake Mafic Intrusion and environment lying near the southern end of the CMB. The intrusion contains gabbro, norite and anorthosite, as well as zones rich in magnetite.

J.E. Campbell (Saskatchewan Research Council) has contributed a report on the Quaternary geology of the Sulphide - Hebden Lakes area. Reports are also included from the SRC by D.H. Quirt and J. Hoeve, and M. Mellinger on a uranium unconformity model and an image analysis method respectively.

The reports on southern Saskatchewan topics include two papers related to petroleum studies by D.M. Lane and L.K. Kreis, a report by C. Boys et al. on clay rocks in the PCS Cory Division Potash Mine, and a summary of mineral- and oil-related research by the Saskatchewan Research Council.

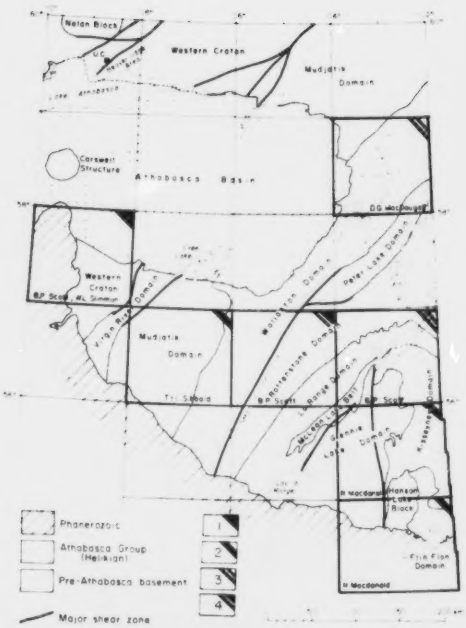


Figure 3 - Location of compilation maps published or in progress in 1986-87. 1 = Compilation bedrock geology 1:250,000 scale final colour version published; 2 = Compilation bedrock geology 1:250,000 scale final colour version in progress; 3 = Compilation metallogenic map 1:250,000 scale in progress; 4 = Compilation metallogenic map 1:250,000 scale published.

## Compilation Maps and Data Files

Fig. 3 summarizes the present state of publication for the 1:250,000 scale Compilation Bedrock Geology and Metallogenic Map Series. One coloured bedrock map and one metallogenic map have been published this year, the latter by B.P. Scott, who has now largely taken over the work on this series. The coloured bedrock maps of the Pelican Narrows and Amisk Lake sheet areas (NTS 64L and 64M) are expected to be released later this winter.

The Saskatchewan Mineral Deposits Index, which lists about 1900 mineral occurrences in the Shield area, has been on mainframe computer for some years. The related manual file, containing brief textural descriptions of the mineral occurrences, is now being updated and transferred to a microcomputer base (T. Uhrich).

The Precambrian Geological Data Files (N. Lee) continue to be developed, using mainframe and microcomputers. A listing of all Saskatchewan geoscientific references has now been transferred to microcomputer, and can be used to generate selected reference lists (R.F. Davie).

**GOLD BELT GEOLOGY PROGRAM (MINERAL DEVELOPMENT AGREEMENT)**
**AND GEOSCIENCE EXPANSION PROGRAM**

Project 8611

# Bedrock Geological Mapping, Windrum Lake Area (Part of NTS 64D-4, 73P-16 and 74A-1)

by C.T. Harper

Harper, C.T. (1986): Bedrock geological mapping, Windrum Lake area (part of NTS 64D-4, 73P-16 and 74A-1); in Summary of Investigations 1986, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 86-4.

The geology of an area of approximately 500 km$^2$, which covers portions of NTS sheets 64D-4, 73P-16 and 74A-1, was mapped at a scale of 1:20,000. This mapping completes the 1:20,000 scale revision mapping begun in 1984 (Harper, 1984, 1985) of the area between Waddy Lake and Star Lake (Fig. 1).

The Windrum Lake area is accessible by float-equipped aircraft from La Ronge and Missinipe, 160 and 80 km to the southwest, respectively. Limited access is provided by Highway 102 along the southeastern margin of the area and conventional watercraft access is rather poor. Aircraft support from Missinipe greatly facilitated mapping in this area.

Project funded under the Saskatchewan component of the Canada-Saskatchewan Subsidiary Agreement on Mineral Development 1984-89

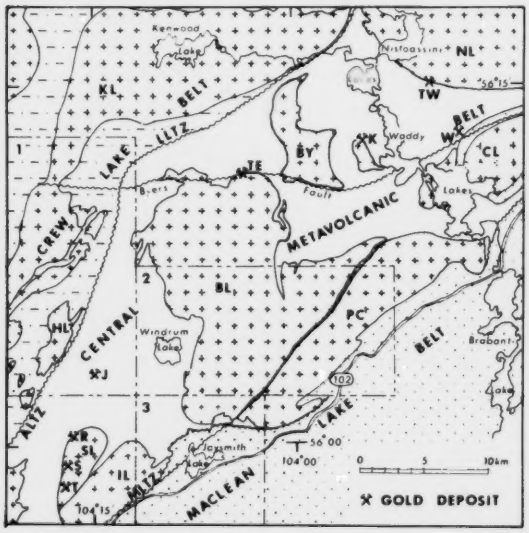


**Figure 1 - Geological sketch showing the location of the areas mapped in 1986 (Windrum Lake Area, Sheets 1, 2 and 3) with respect to the subdomains of the La Ronge Domain. Crosses indicate intrusive rocks, with major plutonic bodies marked: KL, Kenwood Lake; NL, Nistoassini Lake; CL, Contact Lake; BY, Boundary Lake; BL, Brindson Lake; PC, Payn Creek; HL, Hook Lake; IL, Island Lake; SL, Star Lake Plutons. Major tectonic zones are: LLTZ, Looney Lake; ALTZ, Alpat Lake; and MLTZ, McLennan Lake Tectonic Zones. Gold deposits shown are: TW, Twin; W, Weedy; K, Komis and EP; TE, Tower East; J, Jojay; R, Rod-Jolu; S, Star Lake 21 Zone; T, Tamar.**

## Geological Background and General Geology

Portions of the present map area were mapped previously by McLarty (1936), McMurchy (1937), Alcock (1938), Miller (1949), Kirkland (1959), Morris (1961) and Gracie (1965), and many of the gold occurrences were examined in semi-detail by Coombe (1976). Mineral exploration activity has fluctuated since the mid- to late-thirties and is presently focussed on gold mineralization.

The Windrum Lake area lies in the La Ronge Domain, comprising in this area parts of the Crew Lake, Central Metavolcanic and MacLean Lake Belts (Fig. 1), which are dominated by, respectively: psammitic to pelitic metasediments; mafic to felsic metavolcanics and plutons; and feldspathic meta-arenites of the McLennan Group which occur along the northwestern margin of the MacLean Lake Belt. Further southeast the belt is dominated by psammitic to pelitic metasediments. The boundaries between the Central Metavolcanic Belt and the flanking metasedimentary belts are marked by prominent topographic lineaments and zones of more intense deformation. These deformation zones are extensions of the Alpat Lake and McLennan Lake Tectonic Zones (Thomas 1984) to the northwest and southeast, respectively.

As all rocks of the area have been metamorphosed, the term 'meta' is generally deleted to avoid unnecessary repetition. Specific characteristics of the volcanic rocks (e.g., massive, amygdaloidal) are indicated by one or more suffixes on the accompanying maps.

## Metavolcanics

Volcanic rocks occur almost exclusively west of the Brindson Lake Pluton in an elliptical area 20 km long by up to 9 km wide. The volcanics are dominantly mafic with lesser intermediate and felsic rocks and minor intercalated sediments. Pyroclastic types are more abundant than flow types. Despite the effects of regional metamorphism and tectonism, primary volcanic textural and structural features are well preserved. Available facing evidence indicates a general younging of the succession from east to west.

Mafic volcanics comprise about 75 to 80 percent of the volcanic succession, with about equal amounts of pyroclastics and flows. Mafic flows dominate the lower part of the succession in a zone 1 to 2 km wide adjacent to the Brindson Lake Pluton. Dark green hornblende porphyroblasts 2 to 15 mm in dimension comprise up to 30 percent of most of these rocks.

Mafic flow rocks include amygdaloidal and/or feldspar-phyric massive flows as well as amygdaloidal pillowed flows and pillow breccias. In places massive flows can be traced vertically and laterally into flow top and talus breccias. Amygdaloidal flows, which are well developed north of Windrum Lake, contain quartz- and/or feldspar-filled amygdules, which range from 1 to 10 mm in diameter and comprise up to 50 percent of the flows locally. Many of the massive flows contain up to 20 percent plagioclase phenocrysts from 1 to 10 mm in length. Individual pillows range from 20 to 100 cm in maximum size on outcrop surfaces, and are commonly amygdaloidal with quartz- and feldspar-filled amygdules occurring in narrow zones near the upper surfaces as well as in the cores of some pillows. Amygdules in the pillow core tend to be larger ($\geq$1 cm in diameter) than those near the margin. In one locality about 2 km north of Island Lake, concentric lines parallel to pillow margins are interpreted as cooling surfaces. Interpillow selvages are thin and poorly developed, making pillow identification difficult in some places.

The mafic pyroclastic rocks include a wide spectrum of rock types but are dominated by thick and extensive accumulations of feldspar-phyric, locally amygdaloidal, lapilli tuffs and tuff breccias. Finely laminated ash and crystal tuffs, agglutinates, coarse volcanic breccias (possibly debris flows or lahars) are less abundant. Minor flows and pyroclastics of intermediate to felsic composition are also developed locally within this succession.

The mafic lapilli tuffs extend from the area east of Exit Lake (Sheet 1, in map pocket) through the central part of the area to within 2 km of the northern edge of the Island Lake Pluton. Normal fragment size gradation is preserved locally (e.g., 60 m east of Gires Lake). Lateral gradation into coarser tuff breccias and finer ash tuff material are indicative of the relative proximity to eruptive vents.

The coarsest fragments occur in the area north of Hayes Lake, where fragments up to 1 m across were observed. Tuff breccias with fragments 30 to 40 cm in size are present along the western shore as well as 3 km southwest and 2 km south of Windrum Lake. Fragments tend to be more monomictic in the lapilli tuffs and tuff breccias compared to the heterolithic nature of fragments in coarse volcanic breccias.

East of Dicus Lake (Sheet 2, in map pocket), mafic volcanic rocks include black-weathering, finely laminated and well-foliated ash tuffs, and bright to dark green generally featureless rocks that locally contain abundant white quartz and/or feldspar veinlets, masses and layers. These rocks closely resemble the mafic to ultramafic metavolcanics around Lower Waddy Lake (Harper, 1984, 1985).

Intermediate volcanic rocks, generally of andesitic composition, are locally interlayered with the mafic volcanic rocks but are increasingly more abundant towards the 'top' of the volcanic succession. They are also interlayered with felsic metavolcanics and volcanogenic sediments in the area between Hayes Lake and Jojay Lake. Massive feldspar-phyric flows and flow breccias with ash and crystal tuffs are common assemblages; coarser pyroclastics are rare. Hornblende porphyroblasts are also present in the intermediate volcanics but are generally smaller than in the mafic volcanics.

Felsic volcanics include rocks of dacitic to rhyolitic composition. They occur in two major zones: 1) a 1500 m thick zone that extends about 7 km southwest of Partington Lake, and 2) an interlayered sequence of mafic to felsic rocks up to 1000 m thick along the western margin of the volcanic succession which trends southerly for about 6.5 km from Puswawao Lake. A minor zone, 200 m thick and 4 km long, occurs west of Bryenton and Windrum Lakes. Dacitic rocks predominate in all three of these zones.

Southwest of Partington Lake, dacitic ash and crystal tuffs predominate with less abundant feldspar-phyric flows, rhyodacitic tuffs and quartz-phyric rhyolite tuffs. Interlayered mafic flows and tuffs, intermediate tuffs and carbonaceous pyritic argillites comprise up to 20 percent of the succession.

The felsic volcanic zone south of Puswawao Lake contains about equal abundances of dacitic and rhyodacitic/rhyolitic rocks including ash, crystal and lapilli tuffs and tuff breccias. Feldspar-phyric flows and quartz-feldspar rhyolite porphyries (mostly sills) are less common, but are particularly abundant along the top of the succession in contact with the overlying sedimentary sequence. Felsic flows are generally more abundant at the southern end of the zone. A rhyolite flow northeast of a small lake 2 km south of the east end of Puswawao Lake, contains spectacularly well preserved lithophysae indicative of devitrification of

obsidian (Self, 1982). The concentrically-shaped lithophysae are up to 6 cm diameter, slightly flattened and occur in a zone at least 2.5 m thick. Nearby outcrops include dacitic lapilli tuffs, massive dacitic flows and pyritic rhyodacitic tuffs.

A distinctive quartz-stringer stockwork with associated sulphide mineralization (described in the "Economic Geology" section) occurs at numerous locations near the top of this felsic-mafic sequence, most notably at the Jojay occurrence. The host rocks appear to be mainly dacitic but include mafic to intermediate volcanic and sedimentary precursors locally.

The Bryenton-Windrum Lakes felsic zone consists primarily of feldspar-phyric dacitic flows with minor amygdules, flow-top breccia and crystal tuff. Disseminated pyrite is characteristic along much of the zone. Mafic to intermediate flows and tuffs underlie this zone and mafic lapilli tuffs and tuff breccia overlie it.

Metasediments of the Central Metavolcanic Belt

Metasedimentary rocks within the Central Metavolcanic Belt occur principally in 1) a 1 km wide zone which extends 8 km southwest of Partington Lake, and 2) a 1 to 3 km wide area which trends south-southwesterly from Puswawao Lake to the southern edge of map area where it continues into the adjoining Star Lake area (Thomas, 1984, 1985b). There is a coincidental association of these sedimentary sequences with major concentrations of felsic volcanics. Thin discontinuous lenses of greywacke and tuffaceous siltstone,which are difficult to distinguish from fine-grained tuffs, occur in the mafic volcanic succession and a narrow sliver of sediments occurs in the Brindson Lake Pluton.

The sedimentary rocks are predominantly greywacke with a common occurrence of greywacke-argillite couplets, which are characteristic of many greenstone belts and believed to have been largely derived from the volcanic rocks and deposited by turbidity currents (Condie, 1981). Black carbonaceous pyritic argillites (derived from euxinic black shales) are a minor component and may represent the sulphide facies equivalent of oxide-silicate (magnetite-garnet) facies shaly iron formation exposed at and north of Jojay Lake (Jaricka, pers. comm.; Thomas, pers. comm.). Several thin lenses of conglomerate occur adjacent to the felsic volcanics in the Puswawao Lake sedimentary basin and minor intraformational conglomerate occurs at the northeast corner of Bog Lake (Sheet 1, in map pocket). In addition to the well-preserved delicate lamination and bedding of these sediments, other primary sedimentary structures include load casts, flame structures, shallow channel scours, slump folding, small-scale growth faults, graded bedding and ripple laminations.

An andalusite-bearing pelitic variety, 200 to 300 m wide, forms a mappable subunit, west of Bog Lake and in the southeast corner of the same lake. The andalusite occurs primarily as chiastolite with porphyroblasts up to 14 cm long by 2 cm square. The porphyroblasts are typically developed with their long axes oriented down dip in the foliation/bedding plane, although some occur perpendicular to this orientation in the foliation/bedding plane.

The two major sedimentary areas tend to be progressively more psammitic to the west, where interlayered psammitic to pelitic rocks reflect, perhaps, the unroofing of various plutons within the Central Metavolcanic Belt. Primary bedding is still well preserved and load casts, current bedding and channel scours are also locally preserved. One such area of sediments lying 2 km west of Bog Lake may represent a large channel cut into the greywacke-argillite sequences.

The 5 km long, north-trending sliver of isoclinally folded sediments, 200 to 300 m east of Loppe Lake, consists of pelitic and greywacke gneisses with mafic to felsic tuffaceous rocks. Locally a siliceous unit hosts disseminated pyrite and pyrrhotite. These rocks are extensively intruded by dioritic and granitic veins, and are cut by quartz veins.

Metasediments of the Crew Lake Belt

The lithological transition from the Central Metavolcanic Belt to the Crew Lake Belt is marked by an abrupt change from the well-layered/bedded, weakly to moderately deformed and metamorphosed sediments and volcanics to strongly foliated, isoclinally folded and refolded, high-grade, neosomal-rich, monotonous migmatitic gneisses of psammitic to pelitic composition. Highly gossanous but generally sulphide-poor pelitic, psammopelitic and calc-silicate gneisses occur sporadically east of the Kenwood Lake Pluton but form a major subunit west of that pluton. The calc-silicates generally occur as more resistent layers, 4 to 10 cm thick, that contain up to 10 percent finely disseminated pyrrhotite. Also within this subunit are discontinuous rusty-weathering carbonaceous quartz-sericite schists from which the sulphide has been leached. Rare blocks of massive pyrrhotite accompanied by later pyrite veining and nodules attest to the presence of massive sulphide lenses. Southeast of Hook Lake, thinly layered biotitic amphibolite and quartzofeldspathic rocks are believed to represent local interlayers of mafic to felsic tuffs or tuffaceous sediments.

Around Hook Lake the psammitic to pelitic gneisses are intensely migmatized, with granitic neosome comprising greater than 50 percent of the rocks in places. Southeast of Hook Lake the gneisses are complexly interdigitated and invaded by granodiorite of the Hook Lake Pluton.

Metasediments of the MacLean Lake Belt

The MacLean Lake Belt is exposed along the southeastern margin of the map area from Cratty Lake through Jaysmith Lake to Horton Lake and along Highway 102 near Weirzycki and Lindsay Lakes. The McLennan Group, which generally lies northwest of Highway 102, is composed principally of arkose and sillimanite-bearing arkoses, with less abundant conglomerate, pelite and amphibolitic greywacke. Southeast of the McLennan Group, the MacLean Lake Belt comprises psammopelitic to pelitic gneisses, calc-silicates, calcareous pelite, and amphibolitic gneiss of probable igneous origin.

Adjacent to the Central Metavolcanic Belt, the McLennan Group consists of a 20 to 30 m wide zone of amphibolitic greywacke which was possibly derived from the volcanic rocks to the west. Elsewhere along the contact are lenses up to 100 m thick of essentially monomictic conglomerate. Clasts are strongly flattened and consist predominantly of granite, but rare quartz clasts and extremely flattened mafic clasts of uncertain origin also occur.

Southeast of this border zone, the McLennan Group is composed of fine- to medium-grained thinly layered arkoses which are progressively coarser grained and more granitoid in appearance to the southeast. Within these granitoid arkoses, a broad zone, which passes through Jaysmith Lake, is characterized by the presence of quartz-sillimanite faserkiesel. The faserkiesel range from less than a centimetre up to 20 cm in length (in plan view) and have an undetermined maximum length down plunge. Along the southeastern edge of this zone, where the rocks are very strongly foliated, foliation surfaces are composed of quartz-sillimanite-ilmenite aggregates. These sillimanite-bearing rocks terminate abruptly along the major northeasterly-trending Jaysmith Lake Shear Zone which parallels the southeast shore of Jaysmith Lake. Southeast of this shear zone psammopelitic to pelitic gneisses dominate, although areas of arkose and biotitic arkose also occur. The rocks in this part of the belt contain much more granitic neosome and display small-scale isoclinal folds. The calcareous and calc-silicate horizons which occur in this area locally contain disseminated chalcopyrite and pyrite.

Ultramafic Intrusive Rocks

Two small bodies of strongly uralitized pyroxenite less than 100 m in size occur in a granodiorite satellite of the Kenwood Lake Pluton 1500 m north of Scottish Lake (Sheet 1, in map pocket). The southwesternmost body displays extensive polygonal brecciation which felsic veins infill.

Intermediate to Felsic Intrusive Rocks

The intermediate to felsic plutons are subdivided into three groups: Group 1, composite and/or zoned intrusions; Group 2, homogeneous intrusions; and Group 3, late quartz-rich leucogranite intrusions (see also Thomas, 1985a; Harper 1985, Harper et al., in press).

Group 1 composite and/or zoned intrusions are represented by the Brindson Lake Pluton and a number of smaller intrusions.

The Brindson Lake Pluton comprises several distinctive overlapping and cross-cutting intrusive phases. Eight phases are recognized, namely the Narrow Lake, Tower, Brindson, Northeastern, Southern, Dicus Lake, Severson Lake, Severson Leucogranite (Fig. 2). Each of these phases has compositional and mineralogical zoning from simple concentric to asymmetric.

1) The Narrow Lake Phase is a small lobe equivalent to the border facies of the pluton, and consists predominantly of diorite, quartz diorite, minor hornblende gabbro, granodiorite and multiple intrusion breccias. The breccias contain at least four different intrusive components including ultramafic xenoliths, coarse- and fine-grained diorite, and late felsic veins. The Narrow Lake Phase is similar to the marginal zone of the Tower Phase.

2) The Tower Phase has a narrow to broad dioritic to gabbroic marginal zone which apparently grades into a monzonite-granodiorite zone. Granodiorite locally intrudes the diorite and forms the neosome of intrusion breccias. Mafic xenolith-bearing quartz monzonite and granite form the core of Tower Phase. The granodiorite-monzonite variety has a widespread distribution and tends to form a marginal zone to the other major phases. This period of granodiorite-monzonite emplacement will be referred to as the 'older' granodiorite.

3) The Brindson Phase is a large ovoid-shaped mass composed largely of granite and quartz monzonite. Discontinuous remnants of diorite and granodiorite-monzonite form the margins, as in the Tower Phase. Several varieties exist, including porphyritic biotite-hornblende granite, nonporphyritic biotite±hornblende granite and quartz monzonite, and leucogranite. The Brindson Phase partially surrounds the Dicus Lake Phase.

   Small granite-quartz monzonite bodies south of Loppe Lake and immediately south of the Southern Phase were probably emplaced coeval with the Brindson Phase.

4) The Northeastern Phase has two essential components, a granodiorite margin equivalent to the 'older' granodiorite and a tear drop-shaped

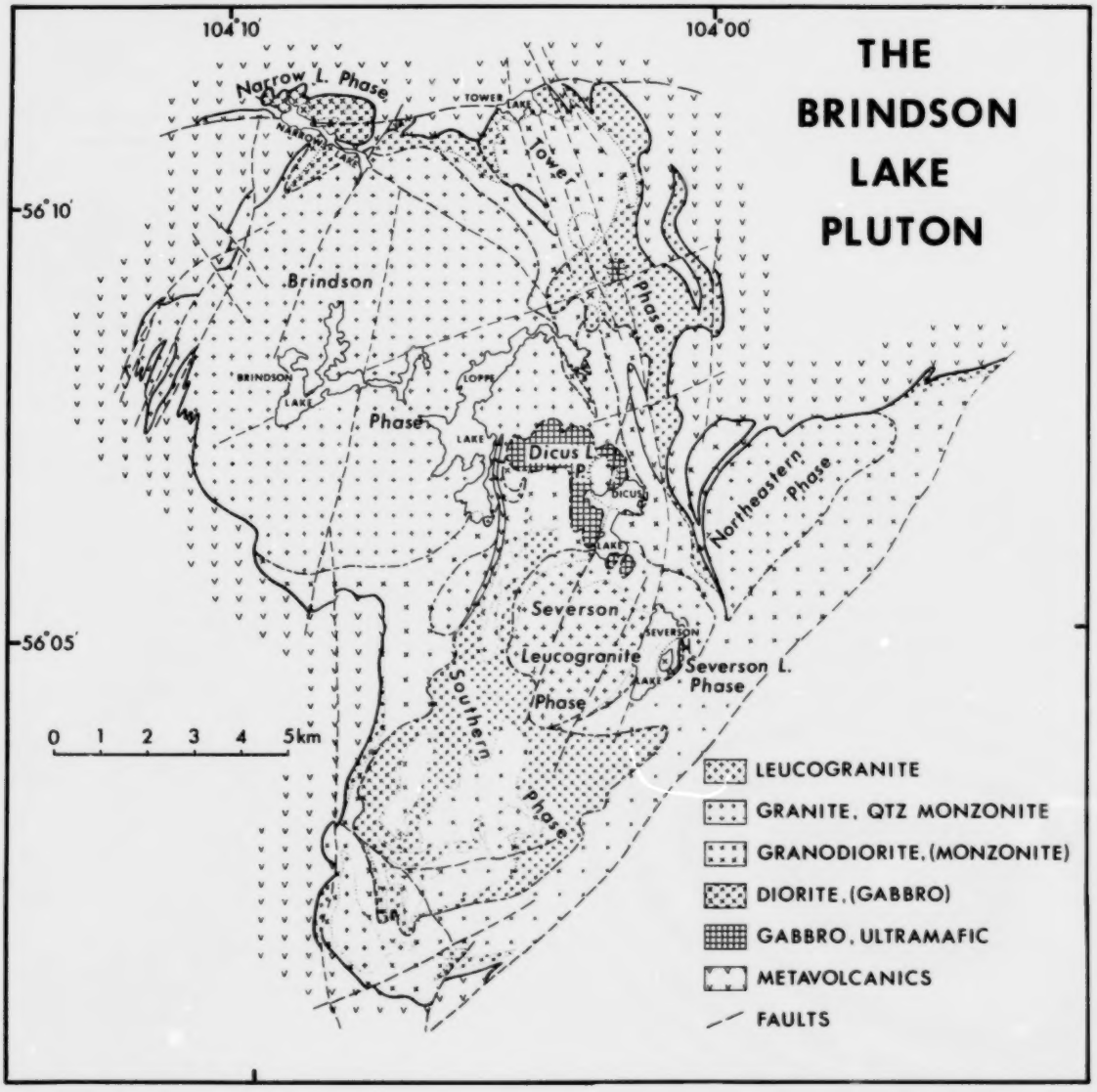


Figure 2 - Anatomy of the Brindson Lake Pluton showing the distribution of the various phases discussed in the text.

core of granite-quartz monzonite which is probably coeval with the Brindson Phase. A narrow remnant of the marginal dioritic variety occurs along the northeast contact with the volcanics.

5) The Southern Phase, which intrudes the 'older' granodiorite variety, comprises an outer zone of diorite, quartz diorite and minor gabbro, which is in turn intruded by a younger granodiorite. Smaller bodies of granite and porphyritic quartz monzonite intruded the younger granodiorite. Xenolithic-rich zones and intrusion breccias occur at the contacts between these different varieties. Along the southern contact of the Southern Phase the marginal zone grades from hornblende gabbro to diorite to monzonite, but the succeeding and more felsic varieties show intrusive rather than gradational relations.

The 'older' granodiorite variety, which forms a kilometre-wide zone southeast of both the Northeastern and Southern Phases, becomes progressively more strongly foliated and mylonitic towards the contact with the Payn Creek Pluton.

6) The Dicus Lake phase is a small zoned body with a narrow magnetite-bearing pyroxenitic margin which is succeeded towards the core by hornblende gabbro, diorite-quartz diorite, quartz monzonite and granite. Each variety contains xenoliths of the preceding varieties. Veins and dykes of the quartz monzonite and granite intrude the other varieties. Multiple intrusion breccia occurs in exposures of the gabbroic to dioritic varieties along the west shore of Dicus Lake. Coarse-grained mesocratic gabbro with local primary igneous layering is in places the intrusive host to an older intrusion breccia, but in a second breccia, it is intruded by a fine-grained diorite. Hornblende gabbros of the Dicus Lake and Southern Phases are very similar in appearance, possibly indicating that they were emplaced coevally.

7) The Severson Lake Phase, which is very similar to the Dicus Lake Phase, is a small ovoid-shaped, zoned body exposed on the east shore of Severson Lake. Magnetite-bearing uralitized pyroxenite forms the eastern margin of the body, and passes into gabbro, diorite and granodiorite-monzonite. The nature of its contacts with the surrounding rocks are not known due to lack of exposure.

8) The Severson Leucogranite Phase has a discontinuous margin of biotite±hornblende granite, which intrudes the Dicus Lake Phase. A large core of generally well-exposed massive quartz porphyritic leucogranite dominates this Phase. The quartz phenocrysts increase in size from 3 to 4 mm at the margins to 15 mm in the interior. Phenocrysts of potash feldspar are rare. Dykes and veins of this leucogranite intrude all of the surrounding rocks, indicating that the leucogranite is the youngest phase of the Brindson Lake Pluton.

Many of the small gabbroic and dioritic sills and stocks which intrude the volcanic succession were probably coeval with the marginal mafic zones of Group 1 plutons. These small intrusions tend to be multiphase and locally sheared, silicified, epidotized and chloritized. Disseminated pyrite and pyritic quartz veins are commonly associated with these deformed and altered zones.

Group 2 homogeneous intrusions include the Kenwood Lake and Payn Creek Plutons, as well as the Kenwood Satellite intrusions and Hook Lake Pluton. Although previously described as predominantly granitic (Thomas, 1985; Harper, 1985; Harper et al., in press), this compositional restriction no longer applies.

The Kenwood Lake Pluton, which occurs entirely within the Crew Lake Belt, is consistently coarse grained (3 to 5 mm), well foliated and homogeneous in appearance, with gradational compositional differences from biotite-hornblende diorite and quartz diorite to granodiorite and rarely granite. The dominantly intermediate composition of the southern part of the Kenwood Lake Pluton contrasts with the northern part of the pluton where granodiorite and granite appear to be dominant. West of Boddy Lake at the north end of Map Sheet 1, numerous veins and dykes of muscovite-biotite granite pegmatite cut the pluton. The consistent northwest trend of these pegmatites indicates tensional fracturing of the pluton in this area. The concentration of pegmatites decreases southward and the orientation changes to northeasterly, approximately parallel to the pluton margin.

The Kenwood Satellite intrusions are irregularly shaped intrusions along the southeastern flank of the Kenwood Lake Pluton. These intrusions are compositionally similar to the Kenwood, being predominantly granodiorite with minor diorite and quartz diorite, but differ in being finer grained (<2 mm), very strongly foliated and interlayered with Crew Lake Belt metasedimentary gneisses. The diorite, quartz diorite and granodiorite west of Hook Lake probably belong to this group and may connect just west of the present map area with the long narrow granodiorite satellite intrusion. The small diorite/granodiorite body north of Partington Lake may also belong to this group of intrusions.

The Hook Lake Pluton is similar in many respects to the Kenwood Satellite intrusions, also possessing a gradational mixture of granodiorite, quartz diorite and diorite, and being fine to medium grained (1 to 3 mm) and well foliated. The southern part of this pluton is complexly interdigitated with Crew Lake Belt metasedimentary gneisses. Locally the intrusive rocks appear to be highly mobilized anatectic melts, but the interdigitations may also be explained by isoclinal folding or sheet intrusion. The smaller ovoid granodiorite/quartz diorite intrusions south of Hook Lake are similar in character.

The Payn Creek Pluton has a narrow granodiorite margin and a discontinuous quartz monzonite/granite zone at the southwest end. The main phase of the pluton consists of a very homogeneous quartz-rich leucogranite, which is similar to the Severson Leucogranite but coarser grained and contain potash feldspar megacrysts. The megacrysts range from 2 to 8 cm long, are up to 5 cm wide and are unevenly distributed, comprising as little as 1 or 2 percent or as much as 20 percent of the rock. Quartz in these rocks is commonly hematite stained due to oxidation of magnetite.

Group 3 quartz-rich leucogranite intrusions include the Windrum Lake and Bryenton Lake Stocks. For the most part these stocks underlie lakes, with only narrow rims exposed along the shorelines. The Windrum Lake Stock consists of a blue quartz leucogranite, with a locally developed granodiorite margin. Fine-grained intermediate and granodiorite dykes cut the stock. Pyritic quartz

veins occur in both the stock and adjacent metavolcanics, which are also extensively epidotized locally. The presence of granite and feldspar porphyry dykes in the surrounding metavolcanics is an indication of the relative proximity to the stock.

The Bryenton Lake Stock is represented by several scattered exposures of quartz monzonite along the southern shore and by blue quartz-bearing leucogranite along the eastern shoreline of the lake.

### Pegmatites

In addition to the pegmatites which intrude the Kenwood Lake Pluton, numerous large pegmatite bodies up to 500 m wide and 2000 m long intrude the metasedimentary gneisses west of the Kenwood Lake Pluton, being especially concentrated around Brown Lake where they comprise nearly 50 percent of the bedrock. These are simple pegmatites, consisting of quartz, potash feldspar, plagioclase, muscovite, lesser biotite and sporadically distributed garnet. Gracie (1965) believed the pegmatites to be related to the Hickson Lake Pluton. The concentration of pegmatites can best be explained as apophyses produced by a volatile-rich acid magma released from an unexposed cupola of the Hickson Lake Pluton lying beneath the area east of Brown Lake. The pegmatites decrease to the north and south but are relatively abundant in the northwest corner of the map area.

### Granites of the MacLean Lake Belt

Dykes, sills and several larger poorly defined bodies of pink- to red-weathering coarse-grained leucogranites intrude the meta-arkoses and pelitic gneisses of the MacLean Lake Belt. Because of their resemblance to granitoid meta-arkoses in the belt, their intrusive character is sometimes difficult to determine. It is speculated that these granites originated through extensive partial melting of the meta-arkoses and pelitic gneisses.

### Quaternary Geology

Glacial, postglacial and glaciolacustrine deposits are widespread througout the area mapped. The most prominent glacial feature is the Cree Lake Moraine which crosses the area from Hicks Lake in the west to Severson Lake in the east where it diminishes. The southern face of the moraine is marked by an abrupt steeply rising boulder-strewn ridge, locally up to 30 m high. Parallel ridges occur immediately behind the front and give way to broad and gently undulating drift-covered areas. Lesser moraine ridges occur up to 10 km north of the main front. The Crew Lake Belt is characterized by more extensive areas of drift cover and peat bogs than the Central Metavolanic Belt.

Glaciolacustrine deposits consisting of white clay are extensively developed in the low-lying areas south of Payn Creek, across the eastern half of the Payn Creek Pluton and extending from Weirzycki Lake to Lower Waddy Lake.

### Structure

The Windrum Lake area has undergone polyphase deformation and is characterized by inhomogeneous strain. Primary sedimentary and volcanic structures are helpful in determining tops and major folds within the Central Metavolcanic Belt, but such features are almost nonexistent in the flanking Crew Lake and MacLean Lake Belts.

Throughout the Central Metavolanic Belt, a finely developed foliation ($S_1$) parallels the original bedding and volcanic layering ($S_0$). The early deformation ($D_1$), to which ($S_1$) is related, is believed to be largely controlled by complementary sinking of the volcanosedimentary pile and the rise of various plutonic bodies. Many $D_1$ folds are closely related to the size, shape and proximity to the plutons, such that a series of local anticlines and synclines are associated with the protrusions and embayments along the edges of the larger plutons. Although some small-scale $D_1$ isoclinal folds occur in the sedimentary/volcanic roof pendants within the Brindson Lake Pluton, small-scale folds are almost nonexistent in the volcanic belt. Opposing bedding top indicators in greywacke/argillite sediments between Jojay and Puswawao Lakes define other major $D_1$ folds. In this area a near vertical, north-trending syncline occurs between the volcanic/sediment contact and the east shore of Bog Lake. A parallel anticline cored by intermediate volcanics trends into the southwest corner of Bog Lake.

The regional northwest compressional deformation ($D_2$) described in the adjacent areas to the northeast (Harper, 1984, 1985) is not well defined in the present area. The major tectonic zones which occur along the boundaries of the Central Metavolcanic Belt and believed to have begun during $D_2$ are described below.

When emplaced, Group 3 plutons caused the local development of triangular pressure shadow-like structures ($D_3$) in the surrounding volcanic rocks. Locally in these structures a weak schistosity ($S_3$) is developed, which is generally oblique to $S_0/S_1$. Drag-folding associated with faulting of different ages is indicated by abrupt deflection of layering/foliation towards the fault traces. A shear fabric (schistosity) is commonly developed over narrow widths parallel to the faults or shears.

In marked contrast to the Central Metavolcanic Belt, the Crew Lake Belt possesses a very strong gneissosity ($S_1$). Although folds ($D_1$) related to the

formation of $S_1$ are not recognized, the $S_1$ surface is isoclinally folded ($D_2$), but apparently without producing a penetrative foliation ($S_2$). $D_2$ isoclinal folding probably occurred on subvertical northeast-trending axial surfaces with steep initial plunges. Subsequent folding ($D_3$) produced open to tight folds of variable attitude and plunges, producing shallow plunges on the earlier isoclines. The $D_3$ folding produced an axial plane cleavage ($S_3$) which locally developed into a stronger penetrative foliation. The polyphase deformation and distinctive folding of the Crew Lake Belt may indicate a much deeper structural level than the Central Metavolcanic Belt.

The MacLean Lake Belt also displays a more intense deformational style, with refolded isoclinal folds, in which a later penetrative foliation has developed. Again the implication is that the MacLean Lake Belt rocks have been at a deeper structural level and are now juxtaposed with the relatively undeformed rocks of the Central Metavolcanic Belt.

The Alpat - Looney Lakes Tectonic Zone (Thomas, 1984, 1985b; Harper, 1985) and the McLennan Lake Tectonic Zone (Thomas, 1984, 1985b) mark the northwestern and southeastern boundaries, respectively, of the Central Metavolcanic Belt. The Alpat - Looney Lakes Tectonic Zone comprises a number of parallel shear zones in the Central Metavolcanic Belt. These zones are defined by the development of mylonitic, extensional (boudinage) and linear fabrics and small-scale folding, and have phyllonites developed from the greywacke/argillite metasediments and schists from the metavolcanics. The deformation is more pronounced on the east side of the shears, a feature also described by Thomas (1984).

The McLennan Lake Tectonic Zone possesses many of the same features as the Alpat - Looney Lakes Tectonic Zone but also shows evidence of late brittle fracturing in the form of fault breccias. The tectonic zone basically follows the contact between the Central Metavolcanic Belt and the McLennan Group, but a prominent northeast-trending splay coincides with the highly deformed contact between the Brindson Lake and Payn Creek Plutons. This zone is marked by strongly foliated, sheared and mylonitic granodiorite and amphibolitic metavolcanics. The mylonite fabric has also been tightly folded into Z-shaped folds.

A period of late brittle fracturing, faulting and shearing was widespread in all three belts and probably caused reactivation and movement along earlier formed faults. Three general trends dominate: north-northeast, northwest and east.

## Metamorphism

The regional metamorphic grade in this part of Central Metavolcanic Belt is upper greenschist to lower amphibolite facies. The grade generally increases towards the margins of the belt and adjacent to the major plutons. Narrow hornfelsic aureoles are preserved around the late quartz-rich leucogranite stocks. Diagnostic minerals of the upper greenschist/lower amphibolite facies in this area include chlorite, biotite, andalusite, garnet and hornblende. The widespread development of posttectonic idiomorphic hornblende porphyroblasts in mafic and intermediate metavolcanics suggests that peak metamorphic conditions outlasted the main period of tectonism. Late shearing and faulting produced retrograde greenschist facies assemblages characterized by chlorite, epidote and muscovite.

In the Crew Lake Belt, the regional metamorphic grade is upper amphibolite facies, as indicated by the presence of abundant anatectic granite and locally preserved sillimanite. Two periods of muscovite growth are indicated; the earlier is prograde and lies parallel to the foliation, whereas the later consists of large idiomorphic flakes oriented perpendicular to the foliation. Some muscovite is believed to be retrograde after sillimanite. Garnet is noticeably absent from the Crew Lake metasediments.

The regional grade in the MacLean Lake Belt is also upper amphibolite, as indicated by extensive sillimanite in the meta-arkoses and by the abundance of anatectic granitic neosome in the gneisses.

Lower amphibolite grade rocks of the McLennan Group are preserved in the narrow arcuate zone adjacent to the metavolcanic belt, as indicated by the presence of epidote and tiny almandine garnets, and the lack of sillimanite and granitic neosome.

## Lithogeochemistry

The lithogeochemical program begun in 1984 was continued in 1986. Samples were collected from the Brindson Lake Pluton and a variety of volcanic and mineralized rocks. The results show similar trends to those already established (Watters, 1984, 1985; Harper et al., in press; Watters, this volume).

## Economic Geology

McMurchy (1937) reported that limited prospecting had been carried out in the region in 1928 and that several claims were staked in 1936 about a mineralized quartz prospect containing gold values; unfortunately, he did not give the location of this occurrence. In 1940, independent prospectors discovered gold just east of Bog Lake (the Jojay showing), which initiated considerable staking in the area. Between 1940 and 1949, the Consolidated Mining and Smelting Co. of Canada Ltd. launched a major gold exploration program which resulted in drilling of the Jojay showing and the discovery of gold showings at Bryenton and Puswawao Lakes (Miller, 1949; Beck, 1959; Coombe, 1984).

Between 1959 and 1963, Augustus Exploration Ltd. explored parts of the area near Exit and Hayes Lake, where they found several low-grade gold showings. E.F. Partridge discovered the Keta showing north of Jaysmith Lake in 1960.

Recent exploration activity has primarily been directed towards further evaluation of the previously known gold showings, particularly the Jojay showing. A significant gold biogeochemical anomaly (Dunn, 1985), located east of Pesimokan Lake along the contact between the Island Lake Pluton and the McLennan Group, has sparked exploration activity along the McLennan Lake Tectonic Zone.

## Gold Mineralization

The majority of the gold occurrences in the Windrum Lake area are structurally controlled sulphide-bearing quartz-filled fractures or shear zones in metavolcanics. Several occurrences at Bryenton Lake are spatially associated with the Bryenton Lake Stock.

Jojay Showing - The Jojay showing is the most developed prospect in the map area. The mineralized zone lies close to the volcanic/sedimentary contact and comprises a zone of brecciation underlying a sequence of felsic tuffs into which quartz-feldspar rhyolite porphyries have been emplaced. The porphyries are in turn cut by mafic to intermediate dykes. The breccia zone, which has been traced for about 2100 m and averages 2 to 3 m in width, consists of a quartz stringer stockwork surrounding angular fragments of country rock which are silicified and contain iron carbonate and biotite. The millimetre- to centimetre-thick veins have been crenulated and folded, suggesting that they were emplaced prior to the regional faulting which is responsible for the prominent north-trending lineament immediately west of the zone. Gold and sulphides, including pyrrhotite, chalcopyrite, pyrite, galena and sphalerite, occur in the quartz and silicified wall rocks (Beck, 1959; Coombe, 1984; Assessment Files[1] 74A01-0011, -0018, -0019). Two grab samples collected by the author from the mineralized zone gave the following results:

| Sample No. | ppm | | | | | | ppb |
|---|---|---|---|---|---|---|---|
| | Cu | Pb | Zn | Ag | As | Cd | Au |
| 8611-266 | 213 | 3,300 | 3,150 | 7.2 | 9.4 | 29 | 4,700 |
| 8611-272 | 361 | 18,000 | 2,070 | 28.0 | 9.9 | 25 | 10,700 |

Drill-indicated reserves at Jojay are estimated to be 368,000 tons grading 0.24 oz./ton Au to a depth of 400 feet (Northern Miner Magazine, July 1986, p.7). Similar style quartz veining was observed during mapping approximately 2 km south of the showing at the same stratigraphic level and approximately 2 km north of the showing but much lower in the section.

Puswawao Showing - An area north of the bend of Puswawao Lake is underlain by felsic and intermediate metavolcanics. Local shearing and silicification have produced a quartz-sericite schist which hosts disseminated pyrite. The adjacent wall rocks are also pyritic and a little chalcopyrite has been observed. Grab samples from this zone yielded trace amounts of gold and silver (Miller, 1949; Beck, 1959). The Saskatchewan Mining Development Corporation conducted diamond-drilling in this area during the 1985-86 winter season, but drilling results have not been released.

Hayes - Exit Lake Showings - A number of small pyritic quartz veins occur in sheared mafic volcanic rocks in the Hayes - Exit Lakes area. The best assay reported is 0.14 oz./ton Au over 1.2 m (Coombe, 1984; Assessment File 74A01-0013). A grab sample taken by the author from the southernmost trench contained 430 ppb Au along with elevated copper and zinc.

Bryenton Lake Showings - At Bryenton Lake, three mineralized northeasterly-trending quartz veins (Nos. 1, 3 and 4) occur in sheared hornfelsic volcanics adjacent to the Bryenton Lake Stock. Finely disseminated pyrite occurs in the wall rocks surrounding the quartz veins, a feature similar to the Komis deposit at Waddy Lake (Harper, 1984). Gold values obtained from trenches across the mineralized structures are consistently higher in the quartz veins than the surrounding rocks. Assays reported from quartz vein No. 1 range from 0.04 oz./ton Au across 30 cm to 0.72 oz./ton across 20 cm (Miller, 1949; Beck, 1959; Coombe, 1984; Assessment Files 74A01-0004, -0027, -0038).

Vein 2, located 300 m northeast of Bryenton Lake, is a narrow, northeast-trending quartz vein within mafic metavolcanics. The best assay from trench samples gave 0.06 oz./ton Au across 3.2 m (Miller, 1949; Coombe, 1984; Assessment File 74A01-0004).

Keta Showing - The Keta showing, located on the east side of a small lake north of Jaysmith Lake, consists of five quartz veins in mafic to felsic volcanic rocks. The southeasterly-trending quartz-filled structures are second-order shears related to the north-trending fault which passes through the small lake and down the west side of Jaysmith Lake. The best assay from the B zone yielded 0.08 oz./ton Au across 20 cm (Assessment Files 74A01-0009, -0010).

## Prospective Gold Targets

Prospective targets in the Windrum Lake area include the following:

[1] Saskatchewan Energy and Mines, Regina

1) The area between Exit Lake and the Brindson Lake Pluton - This area comprises mafic to intermediate metavolcanics, several diorite sills and minor low-grade sulphide facies iron formation. Along numerous north-northeast faults, the volcanics and intrusives are sheared, silicified, epidotized, chloritized and cut by quartz veins containing pyrite and pyrrhotite. The diorite sills also commonly contain disseminated pyrite. The western bulge of the Brindson Lake Pluton has produced many intrusion breccias and is disrupted by numerous fault slices involving granite and mafic volcanics. In addition to the promising geological setting, several gold showings already exist in this area.

2) The Jojay Showing Extension - The intensely faulted volcanic/sedimentary sequence between Puswawao and Jojay Lakes may have been produced from reactivation of old synvolcanic, possible caldera structures. As mineralizing solutions may have travelled along these structures, there is potential for finding modified epithermal-type deposits as well as postmetamorphic vein deposits. Minor iron formation occurs in the overlying sediments as well.

3) The area surrounding the Windrum Lake and Bryenton Lake Stocks - This area has good potential in view of the Komis-style mineralization at Bryenton Lake. Shear zones with weakly pyritic quartz veins occur in both the stock and surrounding volcanics along the south shore of Windrum Lake.

4) The Brindson Lake Pluton - This pluton, which is compositionally similar to the Star Lake Pluton and cut by numerous faults, is essentially unexplored.

5) Along the west side of the Kenwood Lake Pluton - Single grab samples from a pyrrhotite-bearing calc-silicate and a massive sulphide from the zone of gossanous sediments yielded background concentrations of gold. Also quartz veins are more numerous in these same sediments east of Brown Lake where the late pegmatites are most abundant.

6) Finger Lake area - An indication of interesting mineralization was found in quartz vein material stock-piled at an old camp site near the northwest end of Finger Lake. The quartz contains pyrite, chalcopyrite and molybdenite. A grab sample gave the following results:

| Sample No. | ppm | | | | | ppb |
|---|---|---|---|---|---|---|
| | Cu | Pb | Zn | Mo | Ag | Au |
| 8611-608 | 4500 | 13 | 32 | 5000 | 8.8 | 190 |

There is no record of work in this area.

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Project 8612

# Bedrock Geological Mapping, Esmay Lake Area (Part of NTS 73P-10 and -15)

by D.J. Thomas

Thomas, D.J. (1986): Bedrock geological mapping, Esmay Lake area (part of NTS 73P-10 and -15); in Summary of Investigations 1986, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 86-4.

Revisional geological mapping at 1:20,000 scale of the southern part of the La Ronge Gold Belt continued through the Esmay Lake area during June to early September 1986. This mapping forms the southwestern extension of contiguous areas previously examined by the author in the Roundish - Bervin Lakes (Thomas 1985a) and Star Lake (Thomas 1984, 1985b) areas. The main purpose has been to update the existing data base for the area primarily underlain by the metavolcanic-plutonic rocks of the La Ronge Gold Belt. Within the broader scope of this revisional mapping, attention has been focussed on three main objectives:

1) Detailed lithostratigraphic and lithogeochemical documentation of the metavolcanic succession;

2) Examination of the petrological characteristics of the intrusive rocks and their temporal relationship to the volcanics and tectonism;

3) Identification of areas conducive to precious metal mineralization using empirical criteria which characterize known occurrences elsewhere in the belt (e.g., Star Lake Mine and Rod Zone).

The centre of the map area is about 15 km north-northeast of Missinipi and 77 km northeast of La Ronge. Approximately 575 km$^2$ of NTS sheet areas 73P-10 and -15 are covered.

The area investigated has been previously mapped entirely or in part during geological surveys by McLarty (1935), Pearson and Froese (1959), Padgham (1960, 1963), Lewry (1983) and Abraham (1985). The area is also covered by the following geophysical maps:

1) 1:63,360 scale Federal-Provincial aeromagnetic series maps 4790G (Forbes Lake 73P-15) and 4800G (Otter Lake 73P-10);

2) 1:250,000 scale Federal-Provincial aeromagnetic series map 8190G (Lac la Ronge, 73-P).

The Esmay Lake area is included in a recent 1:250,000 scale regional geology compilation of the Lac la Ronge area by Lewry and Slimmon (1985).

Project funded under the Saskatchewan component of the Canada-Saskatchewan Subsidiary Agreement on Mineral Development 1984-89.

## Regional Background

The majority of the Esmay Lake area lies within the Central Metavolcanic Belt of the La Ronge Domain. This belt comprises a varied suite of felsic through mafic metavolcanic assemblages and lesser intervolcanic metasedimentary rock types. Geological and geochemical evidence strongly supports an island arc evolution for the Central Metavolcanic Belt (Harper et al., 1985). Island arc supracrustals have been intruded by a series of uniform to multiphase acid to basic rocks which range from synvolcanic through syntectonic, to posttectonic in age. Also included in this year's mapping are portions of the flanking metasedimentary sequences, the Crew Lake Belt to the northwest and the McLennan Group and MacLean Lake Belt to the southeast. The Crew Lake Belt is composed of a monotonous (back-arc?) succession of psammitic, psammopelitic and minor pelitic rocks which structurally and stratigraphically overlie the main metavolcanic belt. The McLennan Group consists of a monotonous assemblage of feldspathic molasse-like assemblages which structurally underlie the main metavolcanic belt. The McLennan Group grades rapidly southeastwards into a mixed succession of psammitic to pelitic rocks, calc-silicate gneisses, amphibolites and polymictic metaconglomerates termed the MacLean Lake Belt. The transition between the Central Metavolcanic Belt and the McLennan Group is marked by a regionally extensive belt of highly strained rocks referred to as the McLennan Lake Tectonic Zone (Thomas, 1984). The transition between the Central Metavolcanic Belt and Crew Lake Belt appears to be in part gradational between arc-type volcanic and flanking sedimentary assemblages, but it has been locally disrupted by intrusions and by narrow discontinuous zones of cataclasis.

Geochronological investigations using the U-Pb (zircon) method in the Central Metavolcanic Belt (Bickford and Van Schmus, 1985) indicate that major volcanic activity probably took place between 1885 and 1875 Ma ago while major plutonism spanned a period between 1870 and 1830 Ma ago. Peak regional metamorphism affected the rocks prior to 1850 Ma ago (Van Schmus et al.,

1985) but appears to have been followed by a thermal resetting of whole rock and mineral Rb-Sr isotopic systems between 1780 and 1740, coinciding with the conclusion of the Hudsonian event (Bickford and Van Schmus, 1985a; Watters and Armstrong, 1985).

## Synopsis of the Geology

The general geology of the Esmay Lake area is illustrated in Fig. 1.

The geological character of the northern part of the map area is consistent with the main lithostratigraphic and structural elements identified to the northeast (Thomas, 1984, 1985a, 1985b). Original structural and textural features in supracrustal rocks are relatively well preserved in the northern portion of the map area, while a marked progressive mineralogical and textural change in the overall character of the supracrustal rocks is apparent further southwards through the belt. This southwards gradational change is due to 1) an increase in the proportion of intrusive rocks to supracrustals, and 2) an overall increase in metamorphic grade and degree of penetrative deformation affecting the supracrustal cover.

A few potentially important highlights of this year's mapping include the recognition of:

1) A significant proportion of 'volcanogenic' metasedimentary assemblages within the metavolcanic pile, interpreted as a transitional volcanic and epiclastic facies.

2) A major gneissic component in the Bernaski Bay Pluton, as well as a broad migmatitic margin along its northwest side. This intrusion may represent a deeper structural level than is normally exposed and exposure of an older 'basement' element.

3) A composite dyke complex of limited aerial extent intruding metavolcanic rocks around Pawistik Island. At least four episodes of intrusion are identified. These dykes are not seen elsewhere in the map area and may represent one of the oldest intrusive components of the metavolcanic pile.

4) A persistent sulphide-rich calcareous metasedimentary assemblage forming a transitional facies between metavolcanic rocks of the Central Metavolcanic Belt and the metasediments of the Crew Lake Belt. This assemblage may reflect localized exhalative iron enrichment in a back-arc sedimentary platform environment.

5) An overall normal sense of displacement as the youngest measurable movement along theMcLennan Lake Tectonic Zone. The extensional tectonics implied by this last movement suggest a period of 'relaxation' following the main compressional event postulated as being responsible for this regional high strain zone by Lewry (1983).

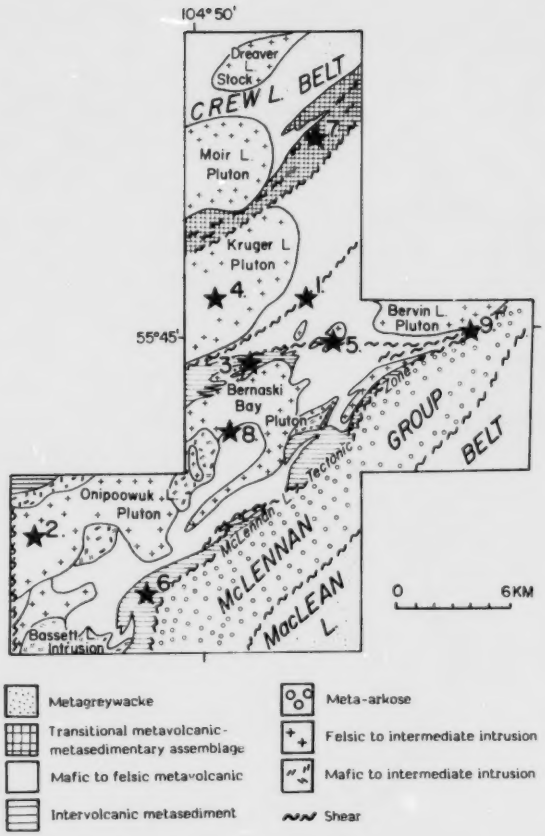


**Figure 1 - General geology of the Esmay Lake area. Numbered stars refer to on "Suggestions to Prospectors" section in text.**

## Central Metavolcanic Belt Supracrustals

The central part of the map area is underlain by a northeasterly-trending belt of metavolcanic rocks about 35 km long and varying in width from 13 km in the north to 8 km in the south. In the south the metavolcanic belt swings into a more north-south direction. The metavolcanic succession is dominated by intermediate to mafic rocks, with felsic varieties generally subordinate throughout the succession. Intervolcanic epiclastic and volcanogenic metasediments are more prevalent in the Esmay Lake area than previously observed in contiguous areas to the northeast (Thomas 1984, 1985a, 1985b). In the north many primary textural and structural volcanic features are well preserved; further south, original features are progressively

less discernible due to regional metamorphism, tectonism and the obliterating effects of increasing plutonism. The proportion of pyroclastic and flow deposits is about equal in the north, while flow-type rocks are more prevalent in the extreme south. A number of distinctive volcanic subareas can be distinguished in detail:

1) In the Esmay Lake area pyroclastics dominate over flow-type units. Mafic rock compositions predominate over intermediate types. Pyroclastic deposits range from feldspar crystal metatuffs through heterolithic lapilli and metatuff-breccias to locally monolithic meta-agglomerates. The majority of pyroclastic deposits are moderately to extremely hornblende porphyroblastic, with individual 'blasts' up to 1 cm in diameter. The coarsest deposits are found towards the east end of Esmay Lake and to the east of Lofvendahl Lake. Fine-grained crystal and laminated ash metatuffs are found towards the northwest part of Esmay Lake. The main pyroclastic package in the Esmay Lake area wedges out to the southwest into a metasedimentary sequence which extends through Kruger and Benjamin Lakes. A 600 to 1000 m wide sequence of intermediate and mafic flows extends northeast through the central part of Esmay Lake and along the west side of Lofvendahl Lake. Flows are variably hornblende porphyroblastic; textures range from feldspar phyric to nonphyric. Individual flow members are relatively thin (generally less than 3 m) while composite flow units are up to several hundred metres thick. Quartz-feldspar-filled amygdules, flow-top breccias and ghosted scoriaceous tops are preserved in some members. Garnet-rich tuffaceous metasedimentary members commonly form interflow beds between mafic metaflows. Towards the west and northwest part of Esmay Lake, metavolcanic rocks are sheared and variably replaced by coarse secondary calcite and/or massive chlorite along a 10 to 200 m wide zone. This zone of shearing and alteration may extend southwest towards Kruger Lake where cataclastic fabrics exist in several narrow zones within predominantly volcanogenic and epiclastic metasediments.

2) A narrow (500 to 2500 m wide) northeast-trending belt of mixed metavolcanic and volcanogenic metasedimentary rocks extends from the east shore of Devil Lake to Bandur Lake. This belt grades from psammopelitic metasedimentary and minor metavolcanic members in the southwest to dominantly interlayered amphibolitic pelites and mafic to intermediate metaflows in the northeast. Minor felsic metavolcanic rocks (metatuffs?) are present locally but are difficult to differentiate from quartzitic and feldspathic psammites because of the effect of later shearing. Cataclastic fabrics are particularly well developed along the southeast margin of this sequence which lies within the McLennan Lake Tectonic Zone. The transition between this mixed succession and the main metavolcanic belt to the northeast is obscured by the southeast margin of the Bernaski Bay Pluton and by several other small stock-like intrusions.

3) The Dickens Lake area provides one of the better exposed and accessible transects across the southeastern margin of the La Ronge Gold Belt. The metavolcanic succession is largely composed of a layered series of northeasterly- to easterly-trending metaflows with minor felsic and mafic lapilli and metatuff-breccias. The pyroclastic units which outcrop along the central portion of Dickens Lake are interlayered with minor volcanogenic metasediments. These pyroclastics and metasediments appear to be the northeasterly termination of the mixed transitional assemblage occurring between Devil and Bandur Lakes described above. A polymictic clast-supported metaconglomerate unit outcrops on several small islands and reefs in the central part of Dickens Lake adjacent to the main high-strain zone which marks the structural break between the Central Metavolcanic Belt and the McLennan Group. The metaconglomerate is made up of an assortment of clasts ranging from well-rounded quartz-rich granitoids to foliated felsic plutonic rocks and metavolcanic clasts. It is interesting to note that the quartz-eye granite clasts in the metaconglomerate are somewhat similar in composition and texture to intrusions along this structural break. Towards the far west end of Dickens Lake, a feldspar diorite porphyry intrudes the metavolcanic succession. The porphyry contains abundant epidote pods and veins, small-scale anastomosing shears and a number of quartz veins.

   As most of the rocks occur within the main part of the McLennan Lake Tectonic Zone, cataclastic fabrics are quite pronounced throughout the Dickens Lake area. Deformation has produced a large-scale anastomosing network of narrow shears separating lozenge-shaped 'tectonic islands' up to 400 m wide and 2000 m in length. Tectonic clasts produced by oblique boudinage and stretching of competent volcanic layers and granitoid veins are particularly well developed in several outcrops close to the main structural break between the Central Metavolcanic Belt and McLennan group.

4) In the Barker Lake area, a mixed assemblage of intermediate pyroclastics and intermediate to mafic metaflows is locally intruded by a composite dyke complex comprising felsic, intermediate and mafic intrusive sheets. In several localities at least four episodes of intrusion can be distinguished, commonly forming up to 90 percent of the outcrop area. Metavolcanic rocks generally occur as small

wedge-shaped slivers between the dykes or as inclusions within them. Good exposures of the dyke complex occur along the north shore of Pawistik Island just downstream of Little Devil Rapids and within shoreline outcrops beside the rapids at the west end of Barker Lake. Towards the east end of Barker Lake, intermediate lapilli metatuffs and metatuff-breccias are prevalent, although lesser amounts of mafic and felsic metavolcanic rocks are also present. A felsic pyroclastic unit outcropping along the east shore of Pawistik Island displays both normal and inverse grading of fine lapilli to tuff-breccia size fragments. In one outcrop an inversely graded section is terminated abruptly by a massive fine-grained felsic top. On the basis of the internal stratification, this felsic unit is tentatively interpreted as a remnant of a pyroclastic flow or surge deposit. A large part of Pawistik Island, as well as the area south of Barker Lake, are underlain by a massive to moderately foliated leucocratic hornblende-quartz-plagioclase rock of broadly 'dioritic' composition. Further petrographic and geochemical analysis will be needed to determine whether this rock type is extrusive or intrusive.

5) Immediately east of Burgess Bay on Hayman Lake, a sequence of mafic to intermediate metaflows with minor pyroclastic and metasedimentary beds occupies a small embayment in the Bernaski Bay Pluton. Flow rocks tend to be feldspar phyric and quite uniform in appearance. It is possible that some outcrops which have been interpreted as flows may be sills of porphyritic microdiorite. Finely laminated ash metatuffs and pelitic metasediments are a minor component throughout the sequence. A series of north-trending metadiabase to metagabbro dykes are particularly prevalent in the northeasternmost corner of this embayment. Similar mafic dykes intrude the Bernaski Bay Pluton and have commonly acted as the loci for later shearing and quartz veining.

6) Poor exposure and marked increase in metamorphic recrystallization of supracrustal rocks in the Wapiyao - Milner - Onipoowuk Lakes area make a coherent interpretation of the primary stratigraphic and depositional relationships difficult. The sequence comprises interbedded pyroclastics and volcanogenic metasediments which are progressively intercalated with mafic to intermediate flows to the southwest. Flow rocks are typically feldspar phyric and amygdaloidal textures are preserved in some outcrops. A distinctive trachytic-textured intermediate to mafic flow, containing tabular feldspar laths up to 4 cm in length which comprise up to 40 percent of the rock, is common about 2.0 km west of Milner Lake. This unit occurs at several structural levels either as separate flows or one flow repeated by folding.

A typically fine-grained mesocratic feldspar porphyritic rock of intermediate or dioritic composition occurs in the area immediately east of Onipoowuk Lake . This rock is generally structureless but in places contains minor bands of recognizable metavolcanic material. The member was previously described by Padgham (1960) as "fine-grained, grey to green, foliated and granulitic rocks" and included with his basic metavolcanic unit. It could represent either a series of thick composite intermediate metaflows or, possibly in part, feldspar crystal metatuffs. Further petrographic analysis of the member is needed to resolve this problem.

Intervolcanic metasedimentary rocks form up to 10 percent of the succession and are largely confined to the southeastern margin of the belt extending from Bandur Lake through Devil Lake to Milner Lake, and an east-trending belt extending from Hayman to Benjamin Lakes. They occur as interflow or intertuff deposits characterized by very thinly bedded (3 to 10 cm) units in which primary sedimentary structures other than compositional layering have been largely obliterated by metamorphic recrystallization and tectonism. Volcanogenic metasedimentary rocks vary from psammitic to psammopelitic and pelitic but most importantly they typically contain a substantial amphibole content (e.g., hornblende, actinolite). Because of their rapid lateral transition into metavolcanic rocks, they are considered to have been derived by rapid reworking of volcanic detritus without significant change in bulk chemical composition. As calc-silicate beds or carbonate-bearing members are absent throughout the sequence, they are not considered to have been derived by metamorphism of calcareous argillaceous sediments such as marls.

Other subareas dominated by either volcanogenic and/or epiclastic intervolcanic metasediments include:

1) A 400 to 1000 m wide, east-trending belt of metasedimentary rocks which extends from Hayman Lake to Benjamin Lake where it interfingers with metavolcanic rocks around the north end of the Bernaski Bay Pluton. This belt varies from a lower sequence of psammitic to psammopelitic epiclastic metasediments to an upper sequence of volcanogenic intermediate to mafic metasediments. A distinctive gossaned quartz-sericite schist and pyrrhotite-bearing calc-silicate assemblage occurs within the lower part of the sequence. The western part of this belt displays a wide variety of metatectite to diatectite features. The metasedimentary rocks are complexly interbanded and gradational with granodioritic gneisses in the western portion of this belt. Between Benjamin and Kruger Lakes, epiclastic and volcanogenic metasediments are cut by a series of northeast- to east-trending narrow shears (less than 25 m wide).

2) Supracrustal rocks underlying the Forbes Lake area represent the transition between the metavolcanic rocks of the Central Metavolcanic Belt and metasedimentary rocks of the Crew Lake Belt. They consist of a northeasterly-trending belt of mixed felsic metavolcanics, calc-silicate gneiss, amphibolite, and psammopelitic to pelitic metasediments. Feldspar porphyry sheets intrude the succession particularly in the southern part of the Forbes Lake area. Intense northeasterly-trending shearing and local mylonitization complicate any interpretation of primary relationships between units. One assemblage of notable interest and potential economic importance is a mixed group of calcareous metasedimentary rocks which includes calcite-bearing pelitic to psammopelitic schist, calcareous quartzitic and psammitic gneiss, amphibolitic pelite, calc-silicate gneiss, and rusty sulphidic quartz-sericite schist. Finely disseminated pyrrhotite and pyrite are abundant in portions of this assemblage, typically occurring in a massive, cherty, pale green calc-silicate rock. Intimately associated rusty schists and limonitic gossans form a series of discontinuous horizons from Bateman Lake (Thomas, 1985b) to McAvoy Lake. This transitional sequence may represent a siliciclastic-carbonate environment occupying a back-arc platform in which local deposition of exhalative lean iron formation occurred.

3) Examination of new outcrop exposures along the recently completed Star Lake mine road reveals new insights into the depositional nature of intervolcanic metasedimentary rocks. A brief review of these exposures is considered necessary to the discussion on intervolcanic sedimentation. A group of recently exposed outcrops along the Star Lake mine road about 7.75 km from its junction with Highway 102 were briefly examined in early September. This section consists of a lower sequence of very thin to medium-bedded andesitic ash-crystal metatuffs and volcaniclastic argillaceous metasediments, and an upper sequence of metaflows and massive crystal metatuff. Primary sedimentary features, well preserved in the lower part of the sequence, include load casts, 'ball and pillow' structures, flame structures, ripple bedding, scour troughs, normal and inverse grading, and convolute bedding. Towards the top of the sequence is a coarser heterolithic poorly sorted debris flow breccia with fine-grained tuffaceous-sedimentary interstitial infill. Internal stratification features of the lower sequence suggest it represents the distal part of a turbiditic sequence derived from volcanic detritus. Bouma series stratification units have been identified in this sequence, and most commonly include ABC, CDE and AE combinations. The presence of small growth-faults attests to a tectonically active depositional environment. Interfingering and overlying this lower sequence are several thin (less than 4 m thick) variolitic feldspar-phyric mafic flows (less than 4 m thick) and a massive feldspar crystal-lapilli metatuff.

The turbiditic volcanogenic metasediments are intruded by a medium-grained leucocratic metadiorite sill, the upper contact of which displays a fine-grained chilled margin and a xenolithic train of country rock. The lower sequence is also intruded by a small feldspar rhyolitic-rhyodacitic porphyry characterized by a sharp discrete lower contact parallel to bedding, and an undulatory upper contact which displays small bulbous protuberances and wedge-shaped apophyses into the wall rocks. Towards the top of this porphyry, amygdule-like quartz blebs and quartz-filled vugs increase in proportion and size. The vugs are locally up to 1.5 cm in diameter and contain well-developed drusy quartz. These features are tentatively interpreted as vapour cavities or miarolitic structures.

These recently exposed outcrops reflect a subaqeous, tectonically active depositional environment in which lava and tuffs were intimately layered with volcaniclastic turbiditic sediments. Synvolcanic intrusions were emplaced within the volcanic-sediment sequence, probably at quite shallow depths as evidenced by the presence of miarolitic cavities.

McLennan Group

The McLennan Group consists of a relatively monotonous sequence of potassium feldspar-rich meta-arenites which include 'granitic' meta-arkose, quartzitic meta-arkose, arkosic metawacke, arkosic muscovite schist and arkosic metaconglomerates. This sequence lies to the southeast of the Central Metavolcanic Belt and is almost everywhere in tectonic contact with the metavolcanics. One exception to this occurs in the Milner Lake area where several thin meta-arkosic horizons occur interlayered with volcanogenic metasediments and minor metavolcanic rocks.

Rocks of the McLennan Group possess a crude compositional and subtle grain size variation within individual beds. Compositional variations in the quartz-feldspar and mica content probably reflect variation in original sand-to-clay ratios. Conglomeratic beds are generally less than 5 m thick and are typically oligomictic, varying from a clast-supported to an arkosic matrix-supported framework. Clasts range in size from pebbles (4 to 64 mm), through cobbles (64 to 256 mm) to boulders (greater than 256 mm) and are almost exclusively granitoid (plutonic), although arkosic, arkosic wacke or mafic clasts are locally present in conglomeratic lenses. A weak to intense tectonic foliation generally parallels or is slightly oblique to bedding throughout the McLennan Group. Fabrics are most intense in rocks along the junction between

metavolcanics and the meta-arkoses. This intense fabric is generally attributed to regional shearing which post dates the main metamorphic fabric in the McLennan Group. Sillimanite-quartz aggregates (faserkiesel) are prevalent in the western part of the McLennan Group. One particularly rich horizon that extends west of Walker Bay on Otter Lake northeast to Devil Lake is probably 200 to 500 m wide and contains faserkiesel aggregates varying from 1 to 30 cm in diameter in a mixed assemblage of arkosic metawackes, meta-arkoses and pebbly arkosic metaconglomerates. Sillimanite is variably retrogressed to coarse muscovite sheaves; the most complete replacement by secondary muscovite occurs along the west margin of the McLennan Group. The McLennan Group is tentatively interpreted as a molasse-like assemblage made up of a repetitious autocyclic fining-upward sequence of fluvial immature lithic and feldspathic sands and conglomerates.

MacLean Lake Belt

Rocks belonging to the MacLean Lake Belt outcrop in the southeastern part of the map area, notably in the Johnson, Walker and Grandmother Bay areas of Otter Lake. They consist of a package of calcareous to noncalcareous psammitic to pelitic metagreywacke, polymictic metaconglomerate, hornblende gneiss and calc-silicate gneiss. The MacLean Lake Belt appears to structurally as well as stratigraphically underlie the more 'arkosic' McLennan Group. The contact between them is quite marked, characterized by little interlayering between the two distinct assemblages. There is a southeastward gradation through the MacLean Lake Belt from well-layered grey psammitic and psammopelitic rocks, through calcareous and noncalcareous pelite and minor calc-silicate into polymictic metaconglomerate. Grey fine-grained psammitic-psammopelitic metagreywackes, which outcrop along the southeastern shore of Walker Bay and in the Grandmother Bay area, range from thinly bedded (1 to 10 cm) to very thickly bedded (greater than 100 cm) members which display even to slightly curved, parallel to nonparallel bedding planes. The assemblage is progressively more pelitic, calcareous and amphibolitic (hornblende, actinolite) to the southeast. In the extreme southeast, polymictic metaconglomerates occur interlayered with mixed psammitic and psammopelitic rocks. The metaconglomerates possess a clast-supported framework of psammitic and psammopelitic cobbles with lesser plutonic and rare mafic clasts. Pure white quartz pebbles are common. The matrix is generally pelitic and commonly contains hornblende, actinolite, diopside, epidote and calcite. Metaconglomerate beds are generally lensoid, display abrupt bases, and fine laterally and vertically into greyish psammites. One small reef exposure in the extreme southeast contains a large psammitic boulder (about 1.5 m in diameter) which appears to have acted as a channel obstruction during deposition of a cobble conglomerate bed. Fine-grained psammite occurs as a triangle-shaped deposit on one side of this boulder while a semicircular crescent-shaped mantle of psammite is found on the other side. This configuration strongly suggests a fluvatile environment. The westernmost exposures of metaconglomerates are extremely deformed and have been affected by shearing which extend from Walker Bay northeast through Grandmother Narrows. Clasts are extremely elongated in this area, making it difficult to recognize the conglomeratic nature of these rocks. To the northeast, the size and number of separate mappable metaconglomerate bodies increase (Padgham, 1963). Rocks of the MacLean Lake Belt in the Otter Lake area are interpreted as derived from a littoral environment in which coarse and sandy alluvial deposits were mixed with limey argillaceous marine sediments.

Crew Lake Belt

The Crew Lake Belt is a monotonous succession comprising interlayered pelites, psammopelites and psammites characterized by very thin (1 cm) to medium bedded (10 to 30 cm) members. Primary layering between members is marked by parallel to nonparallel even beds, although discontinuous and curved bedding is commonly present. Lit-par-lit banding by granitic neosome is widespread around the Moir Lake and Dreaver Lake Plutons; more extensive metatectic migmatization occurs northwest of the Dreaver Lake Pluton. Minor amounts of amphibolitic pelite and hornblende-plagioclase gneiss are present in the area northeast of Crosford Lake.

Major Intrusions[1]

Major intrusions range from felsic through intermediate to mafic in composition. Two or more lithologic varieties are commonly present in most major intrusions.

The Moir Lake Pluton intrudes the Crew Lake Belt and the transitional assemblages of the Forbes Lake area. Contacts with the supracrustal cover are sharp; however, veined and permeated gradational contacts as well as intrusion breccias are locally present. This oval-shaped intrusion underlies about 40 $km^2$ in the Moir - McAvoy Lakes area but only the eastern two-thirds of the intrusion lies within the present map area. The pluton is mainly granodioritic to quartz monzonitic but a narrow dioritic member is present along the south and

[1]All major intrusions in the area have been variably affected by late regional metamorphism; however, for simplicity, the prefix meta- has been omitted from the lithologic names.

east margins. Medium- to coarse-grained porphyritic to nonporphyritic greyish-pink granodiorite-quartz monzonite is the main rock type. A fine-grained equigranular white to greyish white biotite granodiorite-tonalite underlies the area between Girard Lake to McAvoy Lake. Migmatized psammitic metasediments which form a small keel-like outcrop to the northwest of Girard Lake are interpreted as a roof pendant of Crew Lake Belt supracrustals extensively sheeted by granodiorite-tonalite.

The Kruger Lake Pluton is an oval-shaped northeast-trending elongated intrusion which cuts metavolcanic rocks on its east and southeast sides, intervolcanic volcanogenic metasediments along its southern contact, and the transitional assemblage of the Forbes Lake area on the north. Roughly conformable supracrustal units wrap around the northeast end of the body, but northeast-trending shearing has affected the northern margin. The intrusion is composed of three primary members: a narrow leucocratic diorite-monzodiorite which occurs along the east and southeast margins; a coarse-grained greyish-pink quartz monzonite-granodiorite; and a central coarse-grained pink to light greyish-pink porphyritic granite which contains up to 35 percent coarse-grained quartz up to 0.5 cm in diameter. The absence of the diorite phase on the north side of the intrusion may be due in part to late shearing. A number of northeast-trending shear zones cut the pluton southeast of Robertson Bay and northeast of Kruger Lake. Fabrics in these shears range from augen and flaser to protomylonitic and locally mylonitic structure. Rare quartz veins generally occupy dilation or tension fractures within shears.

The southwestern margin of the Bervin Lake Pluton was mapped this year while the main part of the body was mapped during 1985 (Thomas, 1985b). This intrusion forms an elongated northeast-trending body about 11 km by 4 km along the southeast margin of the Central Metavolcanic Belt, where it intrudes metavolcanic rocks of the Central Metavolcanic Belt and meta-arkosic rocks of the McLennan Group. The pluton is dominated by biotite (± hornblende) granite to granodiorite and biotite-hornblende leucodiorite. A dominantly leucocratic diorite-tonalite phase was identified this summer along the southwest margin. This marginal member grades into a medium-grained equigranular granodiorite exposed along the north and northeast shores of Dickens Lake. The southeastern margin has been affected in part by shearing related to the McLennan Lake Tectonic Zone, although the bulk of the strain in this zone has been taken up by the supracrustals along the contact. Extensive epidotization of supracrustal rocks described previously along the northwest flank of the intrusion (Thomas, 1985b) is widespread in metavolcanic rocks along the southwest margin. Late shearing, epidotization, quartz veining and sulphide mineralization are present along the contact of the pluton in metavolcanic and diorite porphyry rocks in several areas at the west end of Dickens Lake.

The Onipoowuk Lake Pluton comprises a number of dioritic to gabbroic bodies which have been intruded and amalgamated by a large uniform body of quartz monzonite and granodiorite. The intrusion underlies an area measuring approximately 14 by 4.5 km extending from Hayman Lake to Faultline Lake and Nipew Lake to Onipoowuk Lake, and intrudes metavolcanic rocks on its southeast side and migmatitic metasediments on its north side. The earliest phase of this intrusion was marked by the emplacement either as a single intrusion or separate bodies of gabbros, dioritic-gabbros and diorites that outcrop along the south shore of Nipew Lake, the south shore of Hayman Lake and around Onipoowuk Lake . The basic rocks along Nipew Lake range from melanocratic to mesocratic gabbro to gabbroic diorite and contain local primary rhythmic layering. Rocks previously mapped by Padgham (1960) as basic metavolcanics in the area southwest of Sluice Falls are reinterpreted as dominantly fine-grained mafic-rich diorite to medium-grained dioritic gabbro, although minor mafic metaflows are also locally present. These early rocks are intruded and partly assimilated by a large body of dominantly porphyritic quartz monzonite and nonporphyritic granodiorite. The intrusive contact between the younger felsic member and earlier basic to intermediate rocks is generally sharp and regular, although narrow zones of monzodiorites and monzogabbros produced by feldspathization are common in the earlier rocks. Fine-grained felsite or aplitic dykes intrude the quartz monzonite and granodiorite but are not observed in the basic and intermediate rocks. Conjugate shear sets, trending north-northeast and east-southeast, transect the pluton between Faultline, Nipew and Onipoowuk Lakes. Quartz veining is locally developed in these shear zones.

The Bernaski Bay Pluton is one of the more complex intrusions in the southern part of the Central Metavolcanic Belt. It sharply intrudes metavolcanic assemblages along its southeast, northeast and southwest contacts, where intrusion breccias are generally well developed. The northeastern contact with metavolcanic rocks is highly embayed. Small stock-like bodies which intrude the metavolcanic succession to the northeast of this embayed margin may be small cupolas related to the main pluton. The northwest contact is poorly defined and marked by a broad migmatitic aureole that separates the pluton from metasedimentary rocks. The main component of the intrusion is a granitic suite ranging gradationally from granodiorite through quartz monzonite to granite. Leucodiorite and quartz diorite occupy a semicontinuous marginal phase which varies from a few metres to as much as 2 km wide. Locally, this dioritic member grades abruptly into dioritic gabbro and gabbro. A lensoid body of magnetite-bearing and dioritic gabbro occurs along the southeast margin of the intrusion. The

northwestern part of the pluton is made up of interbanded granodioritic to tonalitic gneisses, and younger massive quartz monzonite and granite. The gneissic component occurs as parallel layers, rafted blocks, or swirly and folded schlieren within the younger granitoids. The northwest contact of the intrusion is a complex of interlayered granodiorite and metasedimentary rocks. There is a marked progressive granitization of the metasedimentary rocks towards the intrusion. Mafic dykes that occur in the western part of the Bernaski Bay Pluton have acted as the loci for later shearing and emplacement of minor quartz veins.

The oval-shaped Dreaver Lake Stock outcrops around and presumably largely underlies much of Dreaver Lake, intruding psammopelitic metagreywackes of the Crew Lake Belt. Numerous narrow sheets of granodiorite extend northeast from the Dreaver Lake Stock to the Brochu Pluton, northeast of the present map area (Pearson and Froese, 1959), possibly attesting to a genetic/temporal relation between the two bodies. The Dreaver Lake body is largely composed of biotite-muscovite granodiorite. Several textural varieties of this two-mica granodiorite are recognized: a fine-grained member occupying the outer zone and a very coarse member forming the core of the intrusion. Quartz commonly comprises up to 30 percent of the rock in aggregates 0.5 cm in diameter, and micas form up to 10 percent of the rock. The stock has a broad injection aureole comprising a complex of interlayered granodiorite sheets and metasediments. This sheeted migmatite complex is particularly broad on the west side.

The Bassett Lake Intrusion is a U-shaped basic body in the extreme southwest. Only the northern part of the intrusion was mapped this year, the southern portion having been mapped by Padgham (1960). The intrusion forms a distinct regional aeromagnetic high (Federal-Provincial aeromagnetic map 4800G, Otter Lake) attributed to the disseminated magnetite and pyrrhotite. The western flank, which is apparently more basic, consists of assorted mesocratic to melanocratic gabbros, and lesser leucogabbro and anorthositic gabbro. Primary rhythmic layering and preserved orthopyroxene are present in the western part. The eastern limb is less basic, being characterized by mesocratic hornblende diorite and dioritic gabbro, with subordinate gabbroic members. The intrusion of granitoid sheets along its northwest part has caused variable degrees of feldspathization (albitization?), resulting in its alteration to dioritic gabbro. Partial melting of gabbroic country rocks to form anorthositic neosome veins and stringers and ultramafic restite selvages is locally developed in the western part of the intrusion.

Numerous smaller bodies of leucodiorite, granodiorite and granite intrude the supracrustal rocks throughout the map area. Contacts with the country rocks vary from regular and discrete to irregular and gradational. An intrusion west of Bassett Lake is a fine-grained saccharoidal-textured pale pink to greyish-pink biotite granodiorite which is generally massive to weakly foliated, except along the west shore of Bassett Lake where intense shearing has produced mylonitic fabrics.

Medium- to fine-grained plugs and sills of biotite leucogranite which intrude a large part of the McLennan Group are intimately interbanded with and gradational into 'granitic' meta-arkoses on all scales.

## Minor Intrusive Dykes and Sills

### Barker Lake Suite

A suite of felsic to mafic dykes representing as many as four separate intrusive episodes cuts mafic to intermediate metavolcanic rocks in the Barker Lake - Pawistik Island area. This suite does not appear to cut plutonic rocks of the Onipoowuk Lake or Bernaski Bay Plutons, nor does it intrude the McLennan Group. Metavolcanic country rocks generally occur as narrow wedges between the multiple criss-crossing dykes and as small xenoliths incorporated in the dykes, and typically form about 60 percent of the rock mass. Crude compositional layering, suggestions of chilled dyke margins, and intrusion breccias are locally present. The dykes tend to form discrete sheets; local branching of the dykes occurs and somewhat diffuse contact margins characterize some gabbroic varieties. Shearing along the south shore of Barker Lake and on Pawistik Island makes it difficult to distinguish 'dioritic' schists produced from sheared dyke rocks from sheared intermediate to mafic metavolcanics. In one outcrop near the upper end of Barker Lake, the following three episodes of dyke emplacement are identified in mafic metavolcanic rocks (in order of oldest to youngest):

1) fine-grained mesocratic feldspar porphyritic metadiorite,
2) fine- to medium-grained melanocratic metagabbro, and
3) very fine grained feldspar rhyodacite-dacite porphyry.

Nearby a slightly different suite of dykes includes (in order of oldest to youngest):

1) coarse-grained feldspar porphyritic 'salt and pepper' textured metadiorite,
2) coarse-grained hornblende porphyroblastic dioritic metagabbro, and
3) fine-grained metagabbro, and
4) a very fine grained metadacite dyke.

The Barker Lake dyke suite may represent a synvolcanic minor intrusive event comprising multiple feeder dykes. A preplutonic sill and dyke complex was identified to the northeast in the Perepelitz - Cockwill Lakes area (Thomas, 1985).

Bernaski Bay Dyke Swarm

A north-trending diabasic to gabbroic dyke swarm intrudes metavolcanic and plutonic rocks east of Bernaski Bay. These dykes are typically fine-grained, dense and commonly contain disseminated chalcopyrite, pyrite and minor arsenopyrite, as well as secondary minerals such as malachite and erytherite (cobalt-bloom). Where the dykes are sheared, there is commonly a noticeable enrichment and coarsening of sulphides.

Muscovite Granite Dykes

Aplitic to pegmatitic muscovite-bearing granite dykes and sills intrude meta-arkosic rocks of the McLennan Group. Muscovite books and potassium feldspar crystals up to 10 cm in diameter are common in the pegmatite members. The aplite and pegmatite bodies, which vary from tabular sheets with discrete contacts to irregularly shaped bodies with diffuse margins, largely postdate peak regional metamorphism, but are affected by later northeast-trending shearing.

## Structure

The Esmay Lake area shows several episodes of deformation related to regional metamorphism, plutonism and local shearing. All metavolcanic and metasedimentary rocks have been variably recrystallized and foliated, and possess one or more penetrative fabrics.

Primary volcanic and sedimentary features are variably preserved in the northern part of the area. A noticeable decrease in the preservation of original structural and textural features is clearly apparent southwards in the map area. An early schistosity ($S_1$) which is parallel to slightly oblique to primary lithologic layering ($S_0$) is pervasive throughout most supracrustal rocks. This $S_0/S_1$ foliation has a predominant north to northeast trend with steep to moderately steep dips to the west and northwest. A second generation subvertical to steeply northwest-dipping and northeast-trending schistosity ($S_2$) is best developed in metasedimentary rocks of the Crew Lake Belt and McLean Lake Belt, and to a lesser degree in supracrustal rocks of the Central Metavolcanic Belt and McLennan Group. A subtle crenulation foliation occurs in fine-grained metasedimentary rocks of the MacLean Lake Belt where the $S_2$ schistosity cuts the $S_1$ foliation. A shear foliation ranging from augen and flaser structure through protomylonitic to locally mylonitic ($S_3$) is developed within a number of northeasterly-trending zones. This $S_3$ shear fabric transposes $S_0/S_1$ surfaces and overprints $S_2$ schistosity.

Linear fabrics are not particularly prevalent, although an early down-dip 'stretching' fabric ($L_1$) is locally developed in parts of the Central Metavolcanic Belt and in the MacLean Lake Belt. This first generation lineation is defined by elongation of clasts, mineral aggregate streaking, and mineral rodding, all of which lie within the $S_0/S_1$ plane. Second generation linear elements ($L_2$) are produced by the intersection of $S_1$ and $S_2$ foliations and by biotite aggregate elongation. Third generation lineations ($L_3$) are related to areas of shearing and include mineral aggregate rodding (quartz-feldspar and sillimanite-muscovite-quartz), quartz lineation, clast elongation and minor drag fold axes.

Top directions in both the Central Metavolcanic and Crew Lake Belts indicate an overall younging to the northeast. Local reversals in younging directions are due to drag-folding in shear zones and along the margins of intrusives. The earliest folds recognized ($F_1$) are found in the southern part of the area where they are defined by northerly- to northwesterly-trending upright axial surfaces. Major and minor second generation folds ($F_2$) are well developed in the MacLean Lake Belt and McLennan Group, and to a lesser degree in the Crew Lake and Central Metavolcanic Belt. The $F_2$ folds are defined by northeasterly-trending tight to isoclinal structures which are steeply overturned to the southeast. In the southeast, $F_2$ fold axes consistently plunge northeast between 25 and 45°.

Cataclastic deformation occurs in a number of northeast-trending zones or zones of high strain which cut across all major lithologic units and major fold structures. These zones are characterized by heterogeneous strain, with fabrics ($S_3$) varying from moderate (augen structure, well-developed schistosity) to high (flasered fabrics, slaty fracture cleavage, protomylonitic, subphyllonitic) to locally very intense (mylonitic, mylonitic gneiss, phyllonitic). Regional shear zones or zones of high strain are found in a number of locations:

1) The most persistent high strain zone is the McLennan Lake Tectonic Zone (Thomas, 1984) which this year has been traced from Dickens Lake southwest through Bandur, Devil and Barker Lakes. Southwest of Barker Lake the zone swings more to the south and is lost under extensive drift cover. The zone varies in width from 25 to 1000 m, the bulk of the deformation being confined to the hanging wall of the Central Metavolcanic Belt. Deformational fabrics ($S_3$) range from moderate to high to locally very intense, with dips ranging from 25 to 45° northwest and local subvertical dips. Detailed mapping in the Dickens - Bandur Lakes and Barker Lake areas reveal the highly complicated interbranching nature of the shears, with several 'tectonic islands' of relatively undeformed rocks up to as much as 400 m wide and 200 m long.

   Mylonitic to ultramylonitic fabrics characterized by millimetre-scale hartschiefer

banding occur along the zone, implying relatively high temperature ductile compressional deformation. The youngest kinematic indicators in this zone (e.g., microfaulting, drag folding of early mylonitic fabrics, rotation of porphyroclasts) exhibit structures which also suggest the presence of lower grade extensional tectonics with a dominant normal sense of displacement ('northside down') and steep northeasterly net movement. It is tentatively suggested that the McLennan Lake Tectonic Zone was initially a high strain zone with northeastward thrust movement during regional northeast-southwest compression, with normal fault displacements particularly along the sole of the hanging wall block during a post-compressional relaxation episode. This interpretation needs to be substantiated by a regional kinematic analysis of this high strain zone along its entirety.

2) Along the northwestern margin of the Central Metavolcanic Belt shearing extends southwest from Larocque Lake through the Forbes Lake area. Shearing has affected supracrustal rocks across a zone ranging from 100 to 1200 m wide. This zone is narrowest between the Moir Lake and Kruger Lake Plutons, but branches into a broader series of discrete protomylonitic to mylonitic zones to the northeast and southwest.

3) A narrow northeast-trending zone of brecciation and shearing (5 to 200 m wide) cuts metavolcanic rocks in the northern part of Esmay Lake and may extend southwest towards Kruger Lake where mixed volcanogenic metasediments and metavolcanics have undergone moderate to high strain within a zone generally less than 20 m wide.

4) A more easterly-trending zone of cataclasis (generally less than 10 m wide) extends from the north side of Benjamin Lake, south of Esmay Lake to Dickens Lake. Shear fabrics vary from strongly schistose in mafic metavolcanic and metasedimentary rocks to protomylonitic in felsic rock types. Later north-trending cross-faulting south of Esmay Lake probably offsets the shear zone in a number of locations. Elsewhere it converges to the southwest with the Esmay - Kruger Lakes structure in a broader zone of anastomosing shears north of Hayman Lake.

5) Less persistent zones of cataclastic deformation are also identified in a number of other areas: a) between Grandmother Narrows and Walker Bay (Otter Lake), b) between Kruger Lake and Robertson Bay (Forbes Lake), c) between Nipew and Onipoowuk Lakes, and d) between Cosford and Forbes Lakes.

## Metamorphism

Supracrustal rocks in the area have been variably affected by regional metamorphism or local shearing and by early plutonism. Major metamorphic features of the map area include:

1) Mafic to intermediate metavolcanic rocks typically contain hornblende+epidote+biotite+plagioclase±garnet±quartz±diopside. The presence of garnet and occasionally diopside is generally restricted to the southeastern margin of the Central Metavolcanic Belt. Idioblastic hornblende porphyroblasts up to 1 cm in diameter postdate the $S_1$ foliation in these rocks.

2) Garnet, hornblende and biotite coexist in volcanogenic metasedimentary rocks of the Bandur - Devil Lakes area and the area immediately west of Milner Lake.

3) Meta-arkosic rocks of the McLennan Group contain quartz-sillimanite faserkiesel and coarse muscovite-quartz sheaves (retrogressive after sillimanite). Post-$S_1$ muscovite is widespread throughout the McLennan Group.

4) Post-$S_1$ anatexis, as well as post-$S_2$ muscovite and garnet growth, occured in metasediments of the Crew Lake Belt.

5) Retrogression of hornblende-rich metavolcanic and plutonic rocks to actinolite-, chlorite- and biotite-rich rocks accompanied local cataclastic deformation.

6) Saussuritization (epidote+white mica+albite+carbonate) of plagioclase feldspar in granitoid rocks is prevalent in areas of low to moderate cataclastic deformation.

Metamorphic characteristics suggest lower amphibolite facies conditions were attained in the northern part of the Central Metavolcanic Belt. An increase in grade to middle and, locally, upper amphibolite facies occurs southwestwards through the metavolcanic sequence. Middle to upper amphibolite facies grade was reached in the Crew Lake Belt, McLennan Group and MacLean Lake Belt. Early metamorphic assemblages in major high strain zones such as the McLennan Lake Belt appear to have formed under middle to upper amphibolite facies conditions, while later movement along these zones resulted in retrogression to upper greenschist assemblages.

## Mineral Exploration

Previous mineral exploration activity in the area has largely concentrated on base metals. Numerous chalcopyrite-pyrite and pyrrhotite-pyrite showings occur in both the Crew Lake and Central Metavolcanic Belts. Significant base metal mineralization has not been reported to date in

either the MacLean Lake Belt or McLennan Group, although small amounts of disseminated chalcopyrite-pyrite occur locally in rocks around Otter Lake (Padgham, 1960). No gold occurrences have been found in the area mapped this year, although trace gold is reported from several base metal showings around Forbes Lake.

Mineral dispositions currently cover the entirety of the area underlain by metavolcanic and metasedimentary rocks of the Central Metavolcanic Belt, and also extend into the Crew Lake Belt, McLennan Group and MacLean Lake Belt. Exploration work has been undertaken this year in the Milner - Wapiyao Lakes area by Silver Resources Inc., in the Benjamin - Esmay - Dickens Lakes area by SMDC, and around Hayman Lake by Durama Enterprises Limited.

### La Ronge Pyrrhotite Trend

A belt of pyrrhotite-pyrite mineralization occurs in several discontinuous northeast-trending zones extending through the Forbes - Larocque Lakes area and to the northwest in the Crew Lake Belt. This belt of iron-nickel sulphides was first discovered in the early fifties and has been periodically re-evaluated through the sixties and seventies, although no significant new discoveries were made. The mineralization appears to occupy three main zones: 1) along the southeast shore of the northern part of Forbes Lake, 2) northwest of Beatty Bay at the north end of Forbes Lake, and 3) across a broad zone 1500 m wide at the south end of Forbes Lake. These zones comprise part of a regional belt of mineralization referred to as the "La Ronge Pyrrhotite Trend" (Assessment File 73P15-0012)[1]. The mineralization occurs as finely disseminated pyrrhotite and pyrite in cherty massive calc-silicate rock and in a rusty gossaned carbonaceous quartz-sericite schist. These hosts are part of a larger assemblage of mixed calcareous metasedimentary rocks which occurs at the transition between the Central Metavolcanic and Crew Lake Belts. Trace amounts of Au, Ag, Cu and Zn are locally reported from several occurrences in this belt. Significant Zn-Pb mineralization occurs in similar calc-silicate metasediments to the southwest at Borys Lake (Padgham, 1960; Coombe, 1975), where trace Ag and Cu is also reported. Detailed descriptions of the pyrrhotite occurrences in the Forbes Lake area can be found in Assessment Files 73P15-0001, -0002, -0010, -0016, -0027, -0029 and -0033.

### Iron-Nickel-Copper, Nipew Lake

Pyrrhotite-pentlandite-chalcopyrite mineralization is reported in gabbroic rocks along the south shore of Nipew Lake (Assessment Files 73P10-0035, -0038, -0059). In one location along the western boundary of the map area, diamond-drilling reportedly cut an intersection of 1.5 m grading 0.52 percent Cu, 0.31 percent Ni, and 0.01 percent Co with trace Ag and Au (Padgham, 1960).

### Bassett Lake Iron Anomaly

A zone of massive iron mineralization is located about 1000 m south of the map area within the Bassett Lake Intrusion. Mineralization is primarily in the form of titaniferous magnetite (5 to 60 percent of rock) and locally as massive pyrrhotite (up to 20 percent). Preliminary reserve calculations indicate a body 900 m long by 60 m wide by 150 m in depth at an average grade of 20 percent Fe for a total of 27 million tonnes (Harper, 1983; Graham et al., this volume).

### Pyrrhotite-Pyrite-Graphite, Benjamin Lake

Four strongly conductive magnetitic zones, extending in a northeasterly direction through the Benjamin Lake area, were evaluated by Kaiser Mines Ltd. in 1966 by ground magnetic and electromagnetic surveys and five diamond-drill holes. The conductors were attributed to discontinuous pyrrhotite-pyrite-graphite mineralization in sheared metasedimentary rocks (Assessment File 73P10-0028).

### Chalcopyrite-Pyrrhotite, Bandur Lake

A copper-nickel showing associated with a sill of metagabbro intruding metavolcanic rocks is located southwest of Bandur Lake. The mineralization occurs as fine to coarse disseminations of pyrrhotite, pyrite and chalcopyrite in sheared gabbro. The occurrence has been evaluated by geological mapping, geophysics, prospecting and limited diamond- drilling, but was concluded to be uneconomic in scale (Assessment Files 73P10-NE-0023, -0029).

### Chalcopyrite, Esmay Lake

Massive and disseminated chalcopyrite with lesser pyrrhotite and pyrite occur in fine-grained intermediate metavolcanics on the Quartz Group of mineral claims on the south shore of Esmay Lake. Development work on this copper showing was undertaken during 1956-57 by Cree Lake Mining Corporation and included a magnetometer survey, the construction of five trenches and diamond-drilling (Assessment File 73P15-0003). The main zone of mineralization, which is located on a small peninsula at the south end of the lake, has been exposed by three trenches and tested by five X-ray diamond-drill holes. The mineralization is confined to a northeasterly-trending shear that dips steeply northwest. The host rock is a very fine

[1]Saskatchewan Energy and Mines, Regina

grained massive intermediate metavolcanic which may be in part silicified along the shear. Examination of this showing by the author identified the presence of a small feldspar porphyry dyke not previously reported.

Chalcopyrite, Hayman Lake

Significant copper mineralization occurs in a northeast-trending zone about 2000 m long by 100 m wide to the east of Hayman Lake. Development work conducted on the showing includes magnetic, electromagnetic and induced polarization surveys, as well as trenching, mapping and geochemical analysis (Assessment File 73P10-0066). The mineralization comprises primarily chalcopyrite and bornite at an average 4:1 ratio, as well as pyrite, minor arsenopyrite, and secondary copper (malachite, azurite) and cobalt (erytherite) minerals. The author identified north-trending mafic dykes cutting across the mineralized zone. The dykes commonly carry finely disseminated sulphides which appear to have remobilized and concentrated in shears and fractures which cut these dykes, and the immediate metavolcanic wallrocks.

Chalcopyrite-Pyrrhotite-Arsenopyrite, Milner - Wapiyao Lakes

Mildly disseminated chalcopyrite-pyrite and pyrrhotite-pyrite occurs in metavolcanic-metasedimentary rocks in the area immediately west of Milner and Wapiyao Lakes. A limited amount of exploration activity has been undertaken in this area without significant results (Assessment File 73P10-0042). Recent work in the Wapiyao Lake area by Silvera Resources Inc. has uncovered arsenopyrite-pyrite mineralization in mafic to intermediate feldspar phyric metavolcanics.

Suggestions to Prospectors

The potential for significant gold mineralization in the area is considered to be high. Exploration in the La Ronge Gold Belt has focussed on the Star - Waddy Lakes and Sulphide - Preview Lakes areas, and gold exploration in the Esmay Lake area has not been at a comparable level. Based on preliminary observations, the area investigated could be regarded as underexplored, and warrants much higher levels of gold exploration efforts. Several promising areas are identified and are considered as worthy of evaluation (numbers in parentheses refer to locations of the areas on the accompanying geological map):

Esmay Lake (1): The northeast-trending shear which cuts metavolcanic rocks on the west side of the lake includes a carbonate-cemented breccia. The presence of free carbonate within this 'open-textured' structure is considered potentially conducive for metal concentration and precipitation.

Nipew-Onipoowuk Lakes (2): Conjugate shears which cut granitic rocks of the Onipoowuk Lake Pluton commonly contain small-scale en echelon quartz-filled tension gashes. These small-scale tension gashes may be indicative of large-scale dilative structures along these shears. The intersections of conjugate shears are readily recognizable on air photos and present a 'classic' exploration target which warrants investigation.

Benjamin Lake (3): The presence of finely disseminated sulphides in a sheared epiclastic-volcanogenic metasedimentary assemblage within a larger metavolcanic succession is analogous to a Hemlo-type gold setting. A follow-up investigation of this assemblage may be worthwhile.

Kruger Lake (4): Quartz-veining in narrow cataclastic zones within the Kruger Lake Pluton are particularly prevalent between Robertson Bay and Kruger Lake. The minor small-scale sulphide-bearing quartz veins in these zones may indicate the presence of potentially larger vein systems within these shears.

Dickens-Esmay Lake (5): An east-trending structure extends west of Dickens Lake to the south of Esmay Lake. Epidotization, hematization, and sulphide-bearing quartz veins occur along this feature where it cuts across a feldspar diorite porphyry at the west end of Dickens Lake. Related minor shear-splays commonly follow small mafic to intermediate dykes which intrude the porphyry. A silicified metavolcanic outcrop was found about 1000 m south of Esmay Lake along the same structure. The presence of sulphide-bearing quartz veins, silicification, hematization and epidotization is evidence for hydrothermal activity. Where this structure cuts through competent rocks, such as the small granodioritic and dioritic plugs south of Esmay Lake, the potential for tension features and precipitation of hydrothermally transported metals is considered to be high.

Wapiyao-Milner Lakes (6): The presence of disseminated sulphides in sheared metavolcanic and volcanogenic metasediments in this area merits attention. The occurrence of coarse arsenopyrite in a shear-hosted quartz vein in mafic metavolcanics or meta-intrusive rocks west of Wapiyao Lake is somewhat similar to gold mineralization characteristics in the PAP - Preview Lakes area.

Forbes Lake (7): The sulphidic calcareous metasedimentary assemblage which marks the transition between the Crew Lake and Central Metavolcanic Belts is considered to be a particularly favourable setting for precious metal enrichment as previously pointed out by Macdonald (1984). Previous exploration efforts in this area are considered not to have fully evaluated this aspect. These rocks appear to reflect a mixed lean iron formation and carbonate sedimentary assemblage

formed in an arc environment, a setting conducive to large tonnage gold deposits (Ridler, 1970).

Bernaski Bay Pluton (8): The presence of sheared mafic dykes, quartz veins and associated sulphides in granitic rocks of the Bernaski Bay Pluton and adjacent metavolcanics presents a somewhat similar setting to that at Star Lake. The presence of copper and cobalt bloom associated with the sheared mafic dykes suggests that attention might also be directed to analysis for Ag in this area.

McLennan Lake Tectonic Zone (10): This high strain zone is favourable for precious metals, particularly where it is constricted between competent rock masses such as the Bervin Lake Pluton and meta-arkoses of the McLennan Group, as at the northeast end of Dickens Lake. The style of deformation in these narrow constricted zones is more brittle in contrast to the ductile style which occurs where metavolcanic assemblages comprise the hanging wall. A marked increase in en echelon quartz-filled tension gashes, epidotization and hematization generally occurs in rocks within these constricted zones. Similar features are encountered to the northeast along the north end of the Bervin Lake Pluton (Thomas, 1985b), as well as along the southeast margin of the Island Lake Pluton (Thomas 1984, 1985a).

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Project 8622

# Bedrock Geological Mapping, Laonil Lake Area (Part of NTS 63M-11 and -12)

by G.D. Delaney

Delaney, G.D. (1986): Bedrock geological mapping, Laonil Lake area (part of NTS 63M-11 and -12); in Summary of Investigations 1986, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 86-4.

In the Laonil Lake area approximately 180 $km^2$ were mapped at a scale of 1:20,000 (Fig. 1). This area includes parts of NTS sheets 63M-11 and -12.

The broad purpose of this project is to refine our understanding of the geology of the supracrustal rocks and associated intrusives in the Laonil Lake area, and where possible relate this to gold metallogenesis. This area contains one significant gold deposit, the Seabee, as well as several other gold showings.

Some specific aims of the project are:

1) to characterize geochemical, petrographic and stratigraphic attributes of individual rock units;
2) to determine structural relationships;
3) to develop a model for the tectonic evolution of the area;
4) to refine our understanding of the metallogenesis of these rocks and from this develop a model to enhance exploration endeavours.

In addition to the work reported on here, this area was included in two projects of the Geological Survey of Canada, under the Canada component of the Mineral Development Agreement Program. Dunn (this volume) completed an orientation biogeochemical survey over a mineralized portion of the Seabee veins. Ames (Poulsen et al., 1985) carried out additional detailed structural studies of the mineralized shear zones at Seabee.

## Previous Work

Parts of the area were included in early reconnaissance investigations of McInnes (1913) and Satterley (1932). In 1955, Budding and Kirkland (1956) carried out reconnaissance mapping of sheet 63M-11. The southeastern strip of the present map extends into this area. The northeast corner of Lewry's (1977) map contains most of the present map area. The Laonil Lake map area is also covered by two compilation maps, an earlier synthesis by Taylor (1958) of the 1:250,000 Pelican Narrows sheet (63M) and a recent 1:250,000 preliminary compilation by Macdonald (1981) of the Pelican Narrows and Amisk Lake map sheets. This area was included in a reconnaissance lake sediment geochemical survey completed in 1974 (Hornbrook et al., 1975, 1977; Geological Survey of Canada, 1984).

Project funded under the Saskatchewan component of the Canada-Saskatchewan Subsidiary Agreement on Mineral Development 1984-89.

## Geological Setting

The Laonil Lake area is in the Glennie Lake Domain, of the Early Proterozoic Trans-Hudson Orogen (Lewry, 1981; Lewry and Collerson, in press). The domain is characterized by subordinate, narrow, arcuate belts of supracrustals in "early quartz dioritic-granodioritic orthogneiss and later foliated to undeformed dioritic to granitic plutons" (Lewry, 1981, p. 69). Lewry (op. cit.) hypothesized that the Glennie Lake Domain is a remnant microcontinental plate, with an Archean component, that collided with the La Ronge arc. This hypothesis has been revised, however, on the basis of a recent U-Pb dating program of separated zircons (Van Schmus and Bickford, 1984; Bickford and Van Schmus, 1985) from seven samples from the Glennie Lake Domain. One from the Eyahpaise Lake Pluton, and another from a later phase cutting it, yielded ages of 1859±5 Ma and 1836±7 Ma respectively (Lewry et al., in press). The oldest date, 1893±35 Ma, was from a gneiss sample collected south of the map area. Subsequently, the Glennie Lake Domain has been reinterpreted as a fragment of another Proterozic arc that collided with the La Ronge Domain (Lewry and Collerson, in press; Lewry et al., in press).

The map area is underlain by supracrustal rocks and several intrusive bodies. Supracrustal rocks are subdivided into two assemblages, the older Pine Lake Metavolcanics (Lewry, 1977) and the younger Porky Lake Siliciclastics. The Pine Lake Metavolcanics comprise a basal sequence of mafic to intermediate metavolcanics and metavolcaniclastics that are succeeded by felsic metavolcanics, metavolcanic fragmentals and associated coarse to fine metasediments (Fig. 1). The Porky Lake Siliciclastics, a succession of meta-arenites, metawackes, metaconglomerates and biotitic metapelites, are exposed in the Ray Lake Synform (ibid.) in the north-central part.

Early granodiorite and granodiorite gneisses flank the eastern and western margins of the supracrustal belt and intrude mafic metavolcanics in the Pigeon

Lake area. The Laonil Lake Intrusive Complex, a multiphased ultramafic to dioritic intrusion, with layers and xenoliths of mafic metavolcanics, bounds the southwestern margin of the supracrustal belt. The late Eyahpaise Lake Pluton, a leucocratic granodiorite intrusion, intruded the south. The Northeastern Migmatite, an intrusive of similar age with a migmatitic component, intruded the northeast corner of the map area. Massive aplogranite and pegmatite, in the northwest, are the last intrusive phase.

Although a few general observations are made about the structural and metamorphic history of this map area, a detailed interpretation of these facets must await a thorough analysis of both field and laboratory data. A complete legend of lithologic units is contained in the accompanying preliminary field map (map pocket).

Pine Lake Metavolcanics (Unit P)

Metamorphism and metasomatism have combined to mask primary structures in mafic and intermediate volcanic rocks; in contrast, at least locally, primary features are preserved in acid volcanics. Because of changes which have affected most volcanic rocks, for the purposes of mapping, they were subdivided into mafic, intermediate and felsic using the criteria established by the Ontario Geological Survey (Trowell et al., 1978). Even these subdivisions could not be applied rigorously, particularly in the eastern part of the area where feldspar blastesis has commonly masked original mafic contents of the rocks.

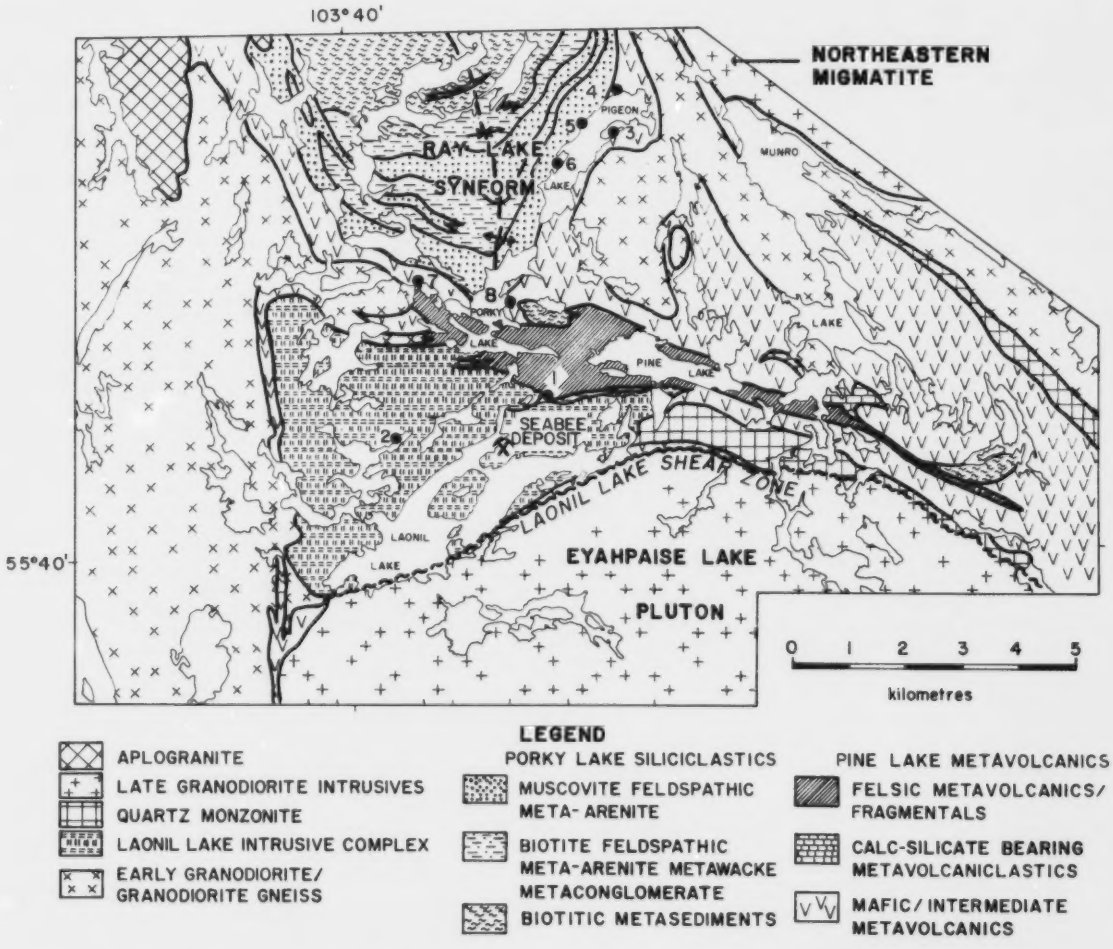


Figure 1 - Geological sketch map of the Laonil Lake map area. Numbered dots are locations of gold showings described in the text: Currie Rose (1), Northwest Laonil Lake (2), P-1 '3), P-2 (4), P-3 (5), P-4 (6), PL-1 (7), PL-2 (8).

### Mafic Metavolcanics (Unit Pvb)

Mafic metavolcanics are present in four areas: 1) along the western margin of the Ray Lake Synform, where they are intercalated with intermediate volcanics and volcaniclastics; 2) in the belt of intermediate and mafic volcanics east and southeast of Munro Lake; 3) mantling the intrusive on the east side of Pigeon Lake; 4) rimming, although somewhat discontinuously, the mafic and ultramafic intrusives in the Laonil Lake Intrusive Complex.

Most typically they are fine grained, dark green and composed of a mosaic of hornblende and plagioclase. This variety is massive to foliated. In some areas they have been recrystallized into medium-grained amphibolites. In the belts of mafic volcanics mantling the intrusives east of Pigeon Lake and the Laonil Lake Intrusive Complex, a common phase is medium- to coarse-grained hornblende in a fine-grained mosaic of hornblende and plagioclase (subunit Pvbp1). In contrast, in the belt southeast of Munro Lake, ubiquitous blastesis has transformed the mafic volcanics into an equigranular mosaic of fine- to medium-grained hornblende and plagioclase that commonly contains millimetre- to centimetre-size blebs of plagioclase (subunit Pvbp2).

### Intermediate Metavolcanics (Unit Pvi)

A thick belt of predominantly intermediate metavolcanics occupies the southeast side of Munro Lake. Intermediate metavolcanics are also intercalated with the mafic metavolcanics and metavolcaniclastics mantling the western side of the Ray Lake Synform. Most intermediate metavolcanics in the Munro Lake area are blastites that range from fine-grained equigranular varieties to more typically those (subunit Pvip) characterized by medium-grained blebs of plagioclase in a fine-grained granoblastic mosaic of quartz, hornblende and plagioclase. This sequence is cut by lenses and pods of leucocratic granodiorite.

The intermediate metavolcanics on the west side of the Ray Lake Synform range from foliated fine-grained varieties near Porky Lake to biotite-hornblende gneisses in the northwest.

### Metavolcaniclastics (Unit Pve)

Within the mafic and intermediate metavolcanics are sequences that were given the field designation metavolcaniclastics. This broad term was applied because, although this subdivision includes both pyroclastic and epiclastic rocks, it is generally impossible to distinguish between the two. One of the most common varieties of metavolcaniclastic is fine-grained, grey to dark grey, and consists of 3 to 15 percent biotite in a mosaic of quartz and feldspar. This variety ranges from massive to compositionally laminated. Another common variety contains variable amounts of disseminated amphibole; still another variety is characterized by variably thick, foliation-parallel layers and lenses of hornblende.

Distinctive calc-silicate-bearing metavolcaniclastics (subunit Pvec), intercalated in metavolcanics and metavolcaniclastics, are exposed near the south-central Munro Lake area. Most typically this subunit is a medium-grained actinolite-cummingtonite-garnet-biotite-plagioclase-quartz rock that ranges from massive to schistose. Proportions of these components are variable. Rare coarse-grained varieties contain rosettes of actinolite or cummingtonite a few centimetres in diameter. Several gossan zones are developed on exposures of the calc-silicate-bearing unit. Although most of these contain only minor pyrite or pyrrhotite, one previously trenched outcrop, on the west side of Munro Lake, contains abundant medium-grained pyrite both in clots and layers.

### Felsic Metavolcanics and Associated Metasediments (Units Pva, Pp and Pr)

In addition to felsic volcanics this subdivision includes metavolcanic fragmentals and metaconglomerates, feldspar porphyry flows, pelitic metasediments, feldspathic meta-arenite and mica schist. Felsic metavolcanics (unit Pva) are fine-grained, foliated to massive rocks composed of quartz and feldspar with minor biotite.

A belt of metavolcanic fragmentals and metaconglomerates (subunit Pvao) extends from the west side of Porky Lake to the southeast corner of the map area. Within this unit, characterized by abrupt facies changes, are grouped a spectrum of fragmented volcanic rocks and coarse epiclastics. Fragments are variably deformed; at some localities they are contorted beyond recognition.

Feldspar porphyry flows (subunit Pvap) are intercalated throughout the belt of fragmental rocks underlying much of the area between the southern part of Porky Lake and Pine Lake. The size of feldspar porphyry bodies varies, from the several hundred metre thick, kilometre long lens between Porky and Pine Lakes, to units that are a few metres thick and die out rapidly along strike. At some localities there is a ryhthmical repetition of feldspar porphyry flows and pebble fragmental units a few metres to a few tens of metres thick. Feldspar porphyry flows are characterized by scattered medium-grained phenocrysts of plagioclase in a fine-grained grey mosaic of quartz, feldspar and biotite. These flows vary from massive to lineated.

To the southwest of Pine Lake is a narrow belt of brownish grey-weathering, thin-bedded pelitic metasediments (unit Pp). This sequence is

characterized by cordierite, staurolite and garnet. Although these pelites exhibit evidence of multiple deformation, primary structures indicative of shallow water deposition are still preserved.

A succession of fine-grained, thin-bedded and laminated light grey feldspathic meta-arenite (unit Pr) and subordinate mica schist (subunit Prs) is exposed along the south side of Pine Lake. This sequence is similar to the muscovite feldspathic meta-arenite sequence (unit PLr) exposed north of Porky Lake in the Ray Lake Synform.

Porky Lake Siliciclastics (PL)

North of Porky Lake, in the Ray Lake Synform (Fig. 1; Johnston, 1968; Lewry, 1971), is a thick sequence of siliciclastics that include muscovite feldspathic meta-arenite, biotite feldspathic meta-arenite to metawacke, metaconglomerate, conglomeratic biotitic feldspathic meta-arenite, and biotite gneiss and schist. The coarse-grained part of this sequence was previously designated the Porky Lake psammites (Lewry, 1977). In this report the entire sequence of sediments in the Ray Lake Synform is designated the Porky Lake Siliciclastics.

Muscovite feldpsathic meta-arenite (unit PLr), the dominant lithology around the margin of the Ray Lake Synform (Fig. 1), is composed mostly of quartz and plagioclase, with muscovite foliae and disseminations. It is typically thin to medium bedded and varies from massive to more commonly laminated. Scattered pebble-size "granitic" clasts are common in many exposures of muscovite feldspathic meta-arenite.

Trough cross-bedding, observed at a few localities, consistently indicates younging to the south. Lewry (1977) and Johnston (1968), however, noted younging in the opposite direction in the Ray Lake Synform. These contradictions might be a structural phenomenon, however, as near its southern end, where the Ray Lake Synform becomes antiformal in character, bedding is apparently overturned.

Biotite feldspathic meta-arenite and metawacke (unit PLrb) are intercalated within the muscovite feldspathic meta-arenite and also occur to the north of it. This typically thin-bedded unit consists of a fine-grained mosaic of quartz and feldspar with minor garnet, and up to 7 percent disseminated biotite and variable amounts of muscovite. Compositional layering is common. Some intervals are rich in amphibole (subunit PLrbc). These range from dark grey to light grey and consist of a fine-grained framework of biotite, quartz and feldspar with 2 to 15 percent, fine- to medium-grained prismatic grains of amphibole.

Although in some outcrops there are distinct amphibole-rich layers, disseminated grains of amphibole are more common. A few of the hornblende-rich layers contain pods of epidote.

Conglomerate and conglomeratic members (subunit Plrbo), a subordinate but significant component of the biotite feldspathic meta-arenite and metawacke, are composed of pebble-size clasts that vary from 5 to 60 percent of the rock, forming an intact to more commonly disrupted framework. Variably stretched clasts consist of quartzitic, "granitic" and feldspathic meta-arenite types.

A thick sequence of biotitic metasediments (unit PLn) is exposed in the core of the Ray Lake Synform. In addition to quartz and plagioclase, this unit contains 7 to 20 percent biotite and minor garnet and sillimanite. Textures vary from massive granulitic to gneissic and schistose. Both narrow, commonly ptygmatically folded, quartz-feldspar veinlets and thick, commonly boudinaged pegmatoid veins are abundant. A few lenses of pebble-size metaconglomerate (subunit PLno) are in this sequence.

Intrusive Rocks

Early Granodiorite - Granodiorite Gneiss (Units Gd/Gdn)

Within this subdivision are several geographically and texturally distinct early and typically granodioritic intrusions.

1) Granodiorite and granodiorite gneiss underlie much of the western side of the map area, forming the boundary of the supracrustal belt. Much of this intrusion is a fairly homogeneous, grey, medium-grained, foliated granodiorite (unit Gd1) composed of about 60 percent plagioclase, 20 to 30 percent quartz, 5 to 7 percent biotite and minor hornblende, and 3 to 5 percent potassium feldspar. The rock characteristically weathers light grey to buff light grey. Local phases are characterized by coarse-grained porphyroblasts of hornblende.

   Along the western edge of the map-area, there are gneissic zones (unit Gdn) within the granodiorite. At the northwestern edge of the map is a heterogeneous terrane comprising various phases of granodiorite, granodiorite gneiss and diorite cut by late aplogranite and associated pegmatites. Elsewhere, such as in the southeast, is a more homogeneous succession of medium- to coarse-grained granodiorite gneiss composed of about 15 percent biotite and hornblende. Segregations of biotite define gneissosity; coarse-grained hornblende porphyroblasts are ubiquitous in the area.

2) A distinctive knobby-weathering granodiorite (unit Gd2) on the southeast side of Pigeon Lake is composed of up to 40 percent extremely lineated and commonly clotted medium-grained quartz in a fine-grained quartz-feldspar mosaic

that contains a few percent biotite and up to 10 percent orthoclase. Potassium feldspar preferentially clots around quartz grains.

There are two marginal zones to this intrusive body. The inner zone is a leucocratic, fine-grained granodiorite that contains some scattered mafic xenoliths and zones with abundant garnet. The peripheral marginal phase is fine-grained mafic metavolcanics and mafic metavolcanic blastites that range from homoblastic to heteroblastic. This marginal phase is cut by pods and lenses of granodiorite.

3) The granodiorite (unit Gd3) on the west shore of Munro Lake is a fine- to medium-grained foliated rock composed of minor pyrite, a few percent orthoclase, 3 to 7 percent biotite and hornblende, and 15 to 35 percent quartz, with the balance plagioclase. Locally within this intrusion, in particular near the margins, are zones of abundant mafic xenoliths. Numerous dykes of pink quartz-feldspar pegmatite cut this granodiorite body.

4) The "granodiorite" (unit Gd4) that parallels the eastern arm of Munro Lake, is megascopically homogeneous in the northwest, but heterogenous towards the southeast. The northwest end of the peninsula separating Munro Lake from its long narrow east arm is underlain by a fine- or locally medium-grained, leucocratic granodiorite that contains 3 to 5 percent biotite, 20 to 35 percent quartz and 60 to 70 percent plagioclase. Near the margins are a few mafic xenoliths. These rocks are cut by massive, pink quartz-feldspar pegmatites. Along the trend of foliation to the southeast is a heterogenous assemblage of paragneiss (unit N) which include the following variants:

   a) Grey, medium-grained, strongly foliated, leucocratic hornblende-biotite-granodiorite. This variety typically contains about 7 percent mafics, with hornblende subordinate to biotite.

   b) Dark grey, medium-grained, strongly foliated mesocratic granodiorite. This rock typically contains 15 to 20 percent mafics with biotite subordinate to hornblende.

   c) Buff, fine-grained, granoblastic metamorphosed feldspathic arenite.

Budding and Kirkland (1956) suggested that this sequence of paragneiss probably formed by granitization.

Quartz Monzonite (units Gq1 and Gq2)

There are two distinct quartz monzonite bodies in the field area. One stretches from the east end of Laonil Lake to the southeast corner of the map area (Fig. 1). The other lies between the heterogenous granodiorite and the thick sequence of mafic to intermediate volcanic rocks on the east side of Munro Lake.

1) The wedge-shaped lens of quartz monzonite (unit Gq1) along the northern margin of the Eyahpaise Lake Pluton is typically salmon coloured and fine to medium grained. This rock is composed of 10 to 17 percent quartz, 5 to 12 percent hornblende and biotite, and approximately equal amounts of orthoclase and plagioclase. Clotted hornblende and biotite commonly define an excellent lineation. This unit was named a hornblende-biotite syenite by Lewry (1977). Mafic xenoliths are abundant near contacts of the quartz monzonite. In the southeast, along the south margin of the quartz monzonite, is a phase composed of 10 to 15 percent orthoclase porphyroblasts, 15 to 17 percent quartz, and 5 percent biotite in a medium-grained plagioclase framework. Quartz monzonite intrudes the volcanic sequence along its northern contact and it is intruded at its southern contact by the Eyahpaise Lake Pluton.

2) The other quartz monzonite intrusive (unit Gq2), east of Munro Lake, is a pink to buff medium-grained leucocratic rock composed of 1/to 2/percent mafics, 25 to 30 percent quartz together with potassium feldspar greater than or equal to plagioclase. This rock is strongly foliated with a protomylonitic fabric near its northeastern contact. In the interior of the quartz monzonite is a massive to weakly foliated phase that megascopically resembles the aplogranite intrusives of the northwestern part of the map area. Staining reveals that this phase varies in composition from granite to quartz monzonite.

Laonil Lake Intrusive Complex (L)

The Laonil Lake Intrusive Complex comprises mostly gabbro and diorite with lesser ultramafic rocks and minor granodiorite, feldspar porphyry, quartz veins, and "green" and "grey" dykes. Although this intrusion was previously named the Laonil metagabbro (Lewry, 1977), it is proposed that it be referred to as the Laonil Lake Intrusive Complex in recognition of its composite character.

A lens of ultramafic rocks (unit Lu) 1000 m long is exposed near the southeastern margin of the complex, and other thin narrow lenses of ultramafic rock are found throughout the body. The ultramafic rocks are commonly dark green and characterized by medium- to coarse-grained hornblende in a fine-grained hornblende groundmass. Relationships are masked between the main ultramafic body and the rest of the intrusion. At other localities, however, some thin ultramafic layers appear to form the basal part of a sequence that grades into gabbro and diorite.

Gabbro (unit Lbb), which is abundant in the southern part of the complex, is typically medium-grained, dark green to greenish-grey and massive. There appears to be a complete compositional spectrum from leucogabbro to melanogabbro. Primary layering has been observed at a few places. Locally within the gabbro are zones several metres thick of fine-grained mafic metavolcanics; elsewhere in the intrusive there are variable amounts of mafic metavolcanic xenoliths. Also present are rare metasediment xenoliths and what are probably intercalated lenses of metagreywacke (unit Lw) and breccia. Gabbro is intruded and fragmented by one or two phases of diorite or quartz diorite. As well, diorite forms discrete bodies between gabbro layers. The diorite in these layers is medium-grained, grey- to greenish-grey, mesocratic and typically chalky-white weathering. Overall the gabbroic portion of the Laonil Lake Intrusive Complex appears to be a sequence of sheets or layers.

Diorite and quartz diorite (unit Lbd) are the predominant rock types in the northwestern third of the Laonil Lake Intrusive Complex. Diorite is texturally and mineralogically variable, ranging from medium- to coarse-grained, and comprising 5 to 20 percent quartz , 20 to 45 percent hornblende and 40 to 70 percent plagioclase. Gabbro that is typically superficially indistinguishable from diorite is a subordinate phase. The proportion of volcanic rocks is higher near the northern margin of the Laonil Lake Intrusive Complex.

Minor components in the Laonil Lake Intrusive Complex are granodiorite, feldspar porphyry, quartz veins, "green" and "grey" dykes. On the Seabee property, the only locality with cleanly stripped exposures, most of these minor rock types show a distinct spatial association with prominent northeast-trending shear zones. These rock types are described in more detail in the discussion of the geology of the Seabee property.

Other than in rarely preserved primary layering and shear zones, much of the Laonil Lake Intrusive Complex appears to be massive. The exception is along the western margin where a prominent mineral lineation is developed.

A hybrid zone created by "gabbro" intruding granodiorite marks the western contact of the Laonil Lake Intrusive Complex. At the southern contact, a narrow belt of mafic metavolcanics (subunit Pvbp1) lies in fault contact with the Eyahpaise Lake Pluton. This prominent fault, here informally named the Laonil Lake Shear Zone, dips steeply to the north and contains a well-developed subvertical lineation.

Along the northern margin of the complex, contact relationships are more ambiguous. On the Currie Rose property, some relationships might indicate the presence of an unconformity between the complex and the overlying supracrustal sequence. These include:

1) The presence of several conglomerate lenses along the contact. Although composed primarily of pebble- and cobble-sized, quartzofeldspathic fragments in an intact framework, there are also a few scattered "gabbroic-looking" clasts within the conglomerates. These clasts could have been derived from the underlying complex.

2) A ubiquitous feldspar porphyry which occurs at or within a few metres above the contact, suggesting the presence of a continuous lithostratigraphic unit extruded after the complex.

3) The variable nature of the gabbro along the contact, including a medium-grained gabbroic phase near the main Currie Rose vein and a fine-grained mafic volcanic sequence 500 m to the east. These relationships possibly suggest that the Lanonil Lake Intrusive Complex had been weathered to various stratigraphic levels.

4) Facing directions in the overlying supracrustals consistently point to the north, away from the Laonil Lake Intrusive Complex. Such a relationship might be expected along an inclined unconformity that tilted away from the intrusive.

Unfortunately, a strong contact foliation in the complex masks the original contact relationships.

Elsewhere, such as north of the Currie Rose vein (No. 1 on Fig. 1), there appears to be an intrusive contact between gabbro and the adjoining sequence of fragmental and thin-bedded metapelitic sediments. At this contact, bedding is contorted and numerous quartz-feldspar veins cut the sequence. Coarse-grained porphyroblasts of cordierite diminish in size away from the contact.

Further to the west, south of Porky Lake, several laterally extensive volcanic layers near the top of the diorite might be cogenetic with this intrusive.

In summary, the Laonil Lake Intrusive Complex is a multiphased layered or sheeted intrusive that evolved in composition from ultramafic to gabbroic and finally to dioritic and quartz dioritic. Xenoliths and intercalated layers of mafic volcanics are abundant.

## Late Intrusives

### Eyahpaise Lake Pluton (unit Egd)

The northern end of the Eyahpaise Lake Pluton lies within the southern part of the map area. Much of this pluton comprises a medium-grained, massive rock composed of 20 percent quartz, 5 to 10 percent potassium feldspar, 60 to 75 percent

plagioclase and 5 to 7 percent mafics that are mostly scattered medium- to coarse-grained porphyroblasts of hornblende and minor fine-grained clotted biotite. Trace amounts of magnetite are common. A few scattered mafic xenoliths are present. As observed by Lewry (1977), textural and mineralogical variations are common in the northern margin of the Eyahpaise Lake Pluton. For example, irregular marginal areas near the eastern margin of the map area contain 20 to 25 percent mafics. Elsewhere, phases contain 5 to 7 percent quartz and no potassium feldspar.

Although there is a prominent foliation near the Laonil Lake Shear Zone, at the northern contact and also along the eastern contact of the pluton (Budding and Kirkland, 1956), in the interior it is lineated to massive. The only foliation observed corresponds to narrow shear zones. In contrast to the sheared contacts noted above, gradational contacts are reported (Lewry, 1977) to characterize the southern and western margins of the Eyahpaise Lake Pluton.

### Northeastern Migmatite (Unit Ngng)

Only a small portion of this unit in the northeastern corner of the field area was mapped (cf. Lewry, 1977). Observed exposures consist of foliated to massive, leucocratic, hornblende-bearing granodiorite with about 20 percent quartz. Locally migmatitic zones contain mafic schlieren and dioritic layers and lenses.

### Aplogranite/Pegmatite (Units Ga and Peg)

The massive aplogranite/pegmatite intrusion in the northwest consists of fine- and medium-grained equigranular quartz and feldspar phases and intermixed quartz-feldspar pegmatites. At many localities there appears to be a gradational contact between the two phases and xenoliths of granodiorite are common. This intrusion is interpreted as a high-level phase of a large aplogranite mass that extends to the north and south (Lewry, 1977; Johnston, 1968).

Surrounding the main aplogranite/pegmatite body is a 2 to 3 km wide zone of country rocks cut by veins and dykes of pegmatite (unit Peg) and subordinate aplogranite, which decrease away from the main intrusive. Most typically, these peripheral phases are quartz-feldspar pegmatite with minor biotite; locally, medium-grained brick red garnets are present. Some pegmatitic phases contain potassium feldspar phenocrysts up to 25 cm in diameter. Several of the pegmatites contain a fine- to medium-grained leucocratic equigranular massive phase composed of about 40 percent quartz, 50 to 60 percent potassium feldspar and plagioclase and minor garnet, magnetite and biotite.

## Age Dating

Two samples were collected in conjunction with the U-Pb zircon geochronology study of the Trans-Hudson Orogen (Bickford et al., 1983; Van Schmus and Bickford, 1984; Bickford and Van Schmus, 1985). One sample, HUD86-29, is a feldspar porphyry from a lens of this intrusive within and southeast of the Vein 13 shear zone at the Seabee deposit. The other sample, HUD86-30, is a quartz diorite from the Laonil Lake Intrusive Complex. The date obtained from the feldspar porphyry should give an approximate age for formation of the gold-bearing quartz- tourmaline veins at the Seabee deposit. Field relationships are interpreted to indicate that emplacement of the feldspar porphyry intrusives was contemporaneous with formation of the mineralized quartz-tourmaline veins.

The age of the quartz diorite should provide a minimum date for the Laonil Lake Intrusive Complex and other correlative ultramafic to mafic intrusives that rim the east and southeast sides of the Eyahpaise Lake Pluton. This date will also provide insight into the timing of these economically important intrusives relative to the evolution of adjacent supracrustal belts.

## Geochemistry

Geochemical characteristics will be determined for a suite of representative samples from the volcanic and intrusive rocks of this area. These data should provide insight into the geotectonic setting in which these rocks were emplaced.

## Economic Geology

A 1959 report by Beck summarized known mineral occurrences. Coombe (1984) included a review of gold showings in his synthesis of Saskatchewan gold occurrences.

Gold is the current focus of exploration activity. Although most interest is centred on the Seabee deposit, other showings are also being actively evaluated.

### Seabee Deposit

The Seabee deposit is located on the peninsula at the northeast end of Laonil Lake (Fig. 1; UTM co-ordinates 586500mE; 6107135OmN). This property was staked by Cominco in 1949. Subsequently, Cominco drilled 117 holes to evaluate the gold potential of the mineralized veins (Coombe, 1984). Claude Resources purchased the property in 1984, completed some additional drilling and carried out an ore reserves study. Claude announced proven and probable reserves for four veins (2, 5, 11 and 14), to a depth of 182 metres of

561,548 tonnes of 11 g/t (0.32 oz./ton) Au, cut (Northern Miner, 1985). Possible reserves to a depth of 305 m were projected to be an additional 454,500 tonnes grading 11 g/t (0.32 oz./ton) Au. In 1985, Placer Development optioned the Seabee property from Claude Resources. By mid-September of 1986, Placer had completed more than 60 additional drillholes as well as extensive overburden stripping of the vein system (Northern Miner, 1986c). Currently, this information is being evaluated and it is anticipated that new reserve figures as well as additional development plans will be announced in the near future.

The Seabee deposit is hosted by the Laonil Lake Intrusive Complex which, in the vicinity of the veins, comprises a series of gabbroic layers or sheets that are cut and commonly capped by quartz diorite. Ultramafic layers or lenses lie at the base of some sheets. Intercalated or rafted within this multiple phase intrusive sequence are variably thick layers, lenses and xenoliths of mafic metavolcanics and minor metagreywacke.

Gold occurs in quartz-tourmaline veins in a series of east-northeast-trending near-vertical shear zones characterized by a prominent steep west-southwesterly-dipping lineation. Narrow sulphide-bearing feldspar porphyry bodies occur within these shear zones. Structural relationships indicate that the gold-bearing quartz veins formed prior to the last major episode of movement in the shear zones. It is interesting to note that the orientation and apparent sense of movement on the shear zones is the same as that in the Laonil Lake Shear Zone at the margin of the Eyahpaise Lake Pluton.

In addition to tourmaline, other minerals associated with the gold-bearing parts of the quartz veins are pyrite, pyrrhotite, chalcopyrite, magnetite and tellurides.

### Currie Rose Vein

This showing is near the northern margin of Seabee claim block (No. 1 on Fig. 1; UTM co-ordinates 587050mE; 6172250mN). A quartz vein 2 to 7 m wide as well as some smaller veins are localized in a series of east-northeast-trending shear zones developed at the contact of the Laonil Lake Intrusive Complex and a lens of conglomerate and pelitic metasediments. Leucocratic granodiorite also intrudes these shear zones. The main vein is milky quartz with some tourmaline-rich zones. Some of the adjacent narrow quartz veins, which are intermixed with sheared intrusive rocks, are generally barren but locally contain clots of fine-grained tourmaline. Three drillholes revealed that the quartz veins thin at depth and contain sparse tourmaline and sulphides (Northern Miner, 1986a).

Cursory inspection of a second showing, located on the northeast arm of the first lake northwest of Laonil Lake (No. 2 on Fig. 1; UTM co-ordinates 584625mE; 6171610mN), revealed a milky quartz vein approximately 1.2 m wide in a medium-grained gabbro. This quartz vein, which appears to trend southeasterly, locally contains up to 10 percent pyrite, both as disseminations and along fractures. A grab sample from here is reported to have contained 8.4 g/t (0.246 oz./ton) Au (Currie Rose Newsletter, June 5, 1986).

### Porky Lake Area Showings

Two showings are known in the Porky Lake area (ibid.):

PL-1: Located on the north side of the middle of three small lakes west of the south-central part of Porky Lake (No. 7 on Fig. 1; UTM co-ordinates 585200mE; 6174500mN). This area is underlain by lineated mafic volcanics. There is an outrop of limonitic breccia along the north shore of the lake. Three drillholes were collared at this site. Hole CR-6 returned 3.9 g/t (0.115 oz./ton) Au for the interval between 102 and 103 m.

PL-2: This showing is on a bay on the east-central shore of the lake (No. 8 on Fig. 1; UTM co-ordinates 586650mE; 6174200mN). A grab sample yielding 1.4 g/t (0.04 oz./ton) Au was taken from this locality. No other information is known about this showing.

### Pigeon Lake Area

Four gold showings are reported from the shores of Pigeon Lake (ibid; Coombe, 1984).

P-1: Located on the prominent peninsula toward the northeast end of the lake (No. 3 on Fig.1; UTM co-ordinates 588500mE; 6177150mN). This is a trenched gossan zone in an outcrop of mafic volcanics cut by an irregular system of iron sulphide-bearing calcareous veinlets and quartz veins. Although a grab sample yielded 12.5 g/t (0.365 oz./ton) Au, 25.0 g/t (0.736 oz./ton) Ag and 2.01 percent Cu, two 100 m drillholes which tested this mineralized zone failed to encounter any ore grade intersections.

P-2: Located at the northwest end of Pigeon Lake (No. 4 on Fig. 1; UTM co-ordinates 588100mE; 6177425mN). A grab sample yielded 1.7 g/t (0.05 oz./ton) Au but there is no additional information.

P-3: This surface showing of unknown character, which yielded 2.7 g/t (0.08 oz./ton) Au, is near the contact between the muscovite feldspathic arenites and the mafic volcanics exposed on the west side of Pigeon Lake (No. 5 on Fig. 1; UTM co-ordinates 588100mE; 6177425mN). A southeasterly-inclined drillhole was collared at this site. A quick review

of the core, which is still on site, revealed that this hole intersected approximately 25 m of banded and disseminated iron sulphides in a sequence of dark greenish-grey garnetiferous volcaniclastics.

P-4: Located on the peninsula near the southwest end of Pigeon Lake (No. 6 on Fig. 1; UTM co-ordinates 587480mE; 6176425mN), this showing is reported to consist of a 6 m wide zone of pyritic quartz veinlets in dark mica schist. A grab sample from an old trench yielded 12.0 g/t (0.349 oz./ton) Au (Coombe, 1984). This showing is at a similar stratigraphic position as P-3.

## Recommendations for Future Prospecting

Favourable sites for gold-bearing quartz veins are shear zones peripheral to and subparallel with the Laonil Lake Shear Zone at the northern and eastern margins of the Eyahpaise Lake Pluton. For reasons not completely understood, shear zones developed in multiphase ultramafic to mafic intrusives seem particularly favourable hosts for gold-bearing quartz veins. For example, in addition to the Seabee deposit in the Laonil Lake Intrusive Complex, other gold-bearing quartz veins have been discovered in the ultramafic-gabbro intrusion at Eisler Lake on the sheared eastern margin of the Eyahpaise Lake Pluton (Northern Miner, 1986b). The economic attractiveness of shear zones in these intrusives is further enhanced by the presence of feldspar porphyry or granodiorite intrusives. The most favourable quartz veins are those with clotted fine-grained tourmaline, iron sulphides and chalcopyrite.

In addition to gold-bearing quartz veins, some of the volcanic sequences might host volcanogenic massive sulphide deposits. For example, the 25 m of banded and disseminated iron sulphides intersected in the drillhole at the P-3 showing on Pigeon Lake could be the distal expression of a massive sulphide body.

## Acknowledgements

This report was enhanced by discussions with Ian Thomson and Ed Kimura of Placer Development Ltd., Peter Gummer of Claude Resources and Bob McLennan of Currie Rose Resources.

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Project 8606B

# Bedrock Geological Mapping, Hebden Lake Area (Part of NTS 73P-7)

by W.L. Slimmon

Slimmon, W.L. (1986): Bedrock geological mapping, Hebden Lake area (part of NTS 73P-7); in Summary of Investigations 1986, Saskachewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 86-4.

A 100 km$^2$ area located 50 km northwest of La Ronge, in NTS sheet 73P-7, was geologically mapped at a scale of 1:20,000. This study was undertaken to establish a regional geological setting with respect to the many areas of gold mineralization in the region. Access to the area is by Highway 102, which defines the map's western boundary, or by float-equipped aircraft. As well, many of the lakes are connected by well-cut portages, and the Contact Lake bush road winds its way past Ramsland Lake down to Preview Lake. Surface topography consists of a series of dominantly northeast-trending low ridges and valleys. Bedrock exposure is fairly limited beneath a sporadic cover of thick moss and Pleistocene to Recent sediments. A thick belt of glacial drift covers most of the area between Contact and Hebden Lakes and north of Hebden Lake.

Previous work in the area was initiated by the Geological Survey of Canada, which in 1936 published a 1 inch to 4 mile scale reconnaissance geology map by D.M.E. McLarty. In 1968 the Saskatchewan Department of Mineral Resources published a 1 inch to 1/2 mile scale map and report by L.H. Forsythe.

## Regional Geology

The map area is situated in the La Ronge Domain of the Trans-Hudson Orogen at the junction of the Crew Lake, MacLean Lake and Nut Bay lithostructural belts (Lewry, 1984). Pelitic to psammitic metagreywackes, metavolcanics and metavolcaniclastics of the Crew Lake Belt are present in the southwest corner of the map area, terminating with the Little Deer Pluton. The MacLean Lake Belt, characterized by a mixture of metagreywackes and metaconglomerates interlayered with metavolcanics and metavolcaniclastics, occupies the central and northern parts of the area. East of these rocks, the Nut Bay Belt consists of a straight belt of subordinate interlayered metagreywackes, metavolcanics and metavolcaniclastics intercalated with granite to granodiorite gneisses (Lewry, 1984).

Project funded under the Saskatchewan component of the Canada-Saskatchewan Subsidiary Agreement on Mineral Development 1984-89.

## Metavolcanic Rocks

Mafic metavolcanic rocks mainly occur in a belt which surrounds Preview Lake and continues intermittently northeastwards between Hebden and Freestone Lakes (Fig. 1). These fine-grained basaltic rocks characteristically weather dark green to black and have a dark grey to black fresh surface. They are primarily weakly foliated to massive and are locally finely laminated or contain metagreywacke intercalations. Networks of anastomosing quartzofeldspathic or calcite stringers are common, and phenocrysts or amygdules are rare. Elsewhere in the map area, mafic metavolcanics are locally intercalated with intermediate metavolcanics.

Intermediate metavolcanics, which were mapped as andesites in the field, are the most abundant metavolcanics and occur throughout the map area. They vary from massive flow rocks to finely laminated tuffs and are consistently hornblendic, very fine grained and medium to dark greenish-grey. The less abundant flow rocks locally contain rounded feldspar phenocrysts rarely exceeding 2 mm in diameter. Pyroclastics include lapilli tuff breccias and rare crystal tuffs but most commonly comprise ash tuffs. The lapilli tuff breccias consist of lens-shaped fragments averaging 3 to 5 cm long with a predominant felsic to intermediate and minor mafic composition; the rocks are primarily matrix-supported but are locally clast-supported, and contain interstitial calcite. The ash tuffs are very finely laminated and generally have a massive appearance. Southeast of Freestone Lake the intermediate metavolcanics commonly contain up to 15 percent disseminated calcite. Anastomosing calcite stringers up to 3 mm wide occur throughout the map area.

Felsic metavolcanics, which are nearly all pyroclastic, are rhyolitic to more dacitic in composition. Well-laminated very fine grained light to dark grey dacitic rocks are most commonly located in the Hebden - Freestone Lakes area. Lapilli tuff breccias, which are predominant in this unit, contain matrix-supported felsic clasts less than 5 cm in length. In many instances disseminated magnetite is associated with these rocks.

Rhyodacitic rocks, which are very fine grained to aphanitic, have a light grey to light brownish-

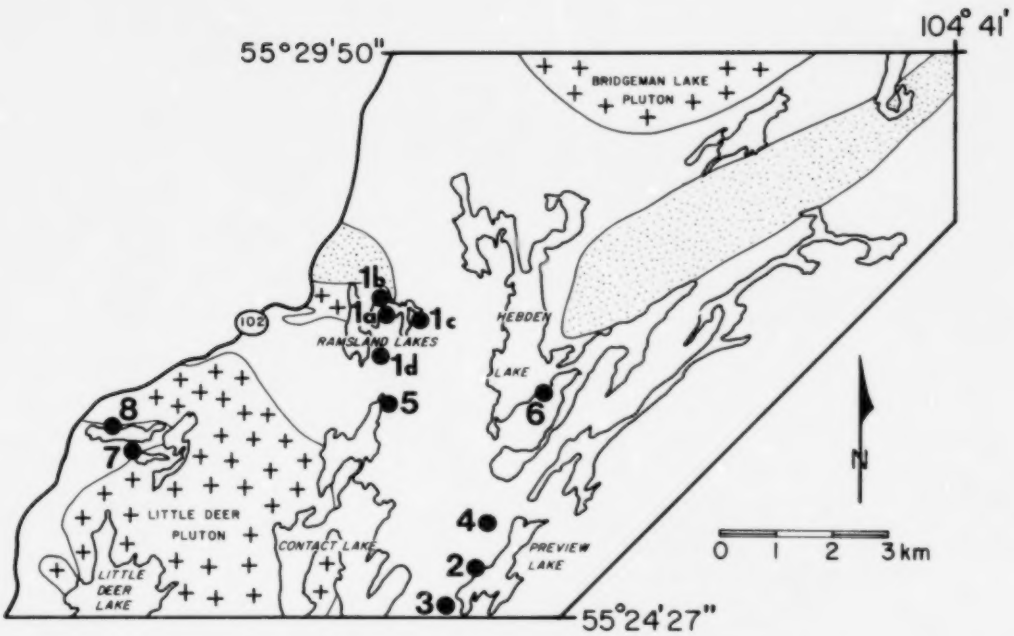


Figure 1 - Simplified geology and major gold showings of the Hebden Lake area. Undifferentiated metavolcanics and metasediments (white), conglomeratic meta-arkose (stipple), major intrusions (crosses). Gold showings: Ramsland 'Centre' (1a), Ramsland 'North' (1b), Ramsland 'East' (1c), Ramsland 'South' (1d), Preview North (2), Preview South - PAP C (3), Preview Lake - Joe (4), North Contact Lake (5), Socko-Tyon (6), Upises Lake (7), Teneycke Lake (8).

grey colour, and usually comprise well-laminated ash tuffs as well as tuff breccias.

Rhyolites are the least abundant of the felsic metavolcanics and usually occur as narrow intermittent bodies. These aphanitic to very fine grained cream to light brownish-grey rocks are finely laminated and rarely quartz phyric. Narrow unmappable layers a few metres wide occur locally in other felsic and intermediate metavolcanics.

## Metasedimentary Rocks

Calc-silicate rocks primarily exist as fine- to very fine grained greenish-grey intercalations in metavolcanic and metagreywacke rocks. Calcite, actinolite-tremolite and diopside are common, as also are epidote pods and thin aphanitic chert layers. The rocks are usually well banded, but are locally quite deformed or brecciated, as for example on the penninsula on the southeast shore of Contact Lake. A light brownish-cream fine-grained skarn outcrops in a small area adjacent to the margin of the Little Deer Pluton on the north shore of Teneycke Lake. Rare poikiloblastic idocrase crystals were reported from this area by Forsythe (1968).

Metagreywacke occurs throughout the map area, both as thin intercalations within metavolcanics and as thick discrete units paralleling the metavolcanics. These well-laminated fine- to very fine grained grey to black rocks are characterized by the presence of biotite and a granular to dull earthy texture. Garnet up to 5 mm in diameter occurs locally. Magnetite and pyrite are common in the metagreywackes, and several gossans are present southeast of Hebden Lake where cherty carbonaceous and argillaceous layers are locally associated with the mineralized zones. Graded bedding suggests that this sequence is younging to the southeast.

Meta-arkosic rocks occur in two separate parts of the map area. The largest body, located northeast of Hebden Lake, occurs in a large synform 1.5 km wide and over 6 km long. This fine- to medium-grained moderately foliated light grey rock comprises quartz, feldspar, muscovite and minor biotite. The meta-arkose is locally slightly migmatized, resulting in zones of medium-grained granitic neosome and narrow medium- to-coarse-grained pegmatitic crosscutting veins. Meta-arkose clasts up to 15 cm long are isolated throughout the main body as well as in conglomeratic layers one to two metres wide. A smaller occurrence of more granitic appearing meta-arkose is present northwest of Ramsland Lake. Here the rock is conglomeratic and contains clasts derived from the quartz-eye granite which outcrops immediately to the south. The clasts are

up to 1 m in diameter adjacent to the contact, which is a possible unconformity (Lewry, this volume).

Metaconglomerates outcrop in several localities. Metavolcanic, granitic and quartz pebble clasts range from small pebbles to boulders up to 100 cm in size in an arkosic or greywacke matrix. Northeast of Hebden Lake, an arkosic metaconglomerate layer up to 100 m wide rims the large meta-arkose body situated there. Moderately sorted felsic metavolcanic, granitic and quartz pebble clasts up to 10 cm long are primarily matrix-supported here but some narrow clast-supported layers are present. The clasts range from very flat metavolcanic fragments to very round quartz pebble and granitic clasts. At the south end of Hebden Lake, arkosic metaconglomerate with primarily felsic metavolcanic and quartz pebble clasts grades into a similar polymictic metaconglomerate containing more granitic clasts and a greywacke matrix. Most other metaconglomerates in the map area are polymictic, containing both granitic and predominantly felsic metavolcanic clasts in a fine-grained biotitic greywacke matrix.

## Intrusive Rocks

Intrusive rocks range from leucogranite to gabbro in bodies ranging from small dykes and sills to large zoned plutons.

The largest intrusion in the area is the Little Deer Pluton which ranges from granite in the centre, outwards through granodiorite and quartz-diorite to diorite. Fine- to medium- grained quartz-eye leucogranite locally occurs in the centre of the granitic phase of the pluton. This pinkish-orange massive to weakly-foliated rock contains 30 to 40 percent quartz with irregular to oval-shaped quartz grains and less than 5 percent biotite. The quartz-eye leucogranite grades into medium-grained cream to pink massive to weakly foliated granite with a biotite content averaging 5 to 10 percent. Hornblende is locally present and quartz averages 30 percent of this rock. Surrounding the granite a slightly more mafic medium-grained massive to weakly foliated granodiorite phase contains 20 to 25 percent quartz and 20 percent total of about equal amounts of biotite and hornblende. Quartz diorite containing 5 to 10 percent quartz and 25 to 30 percent mafics occurs in a transition zone between the granodiorite and outermost diorite phase. The main body of diorite, mainly occurring in the north but also outcropping farther south around Little Deer Lake, is a massive medium-grained grey rock generally containing 30 to 40 percent hornblende, with phenocrysts up to 5 mm, as well as accessory biotite and quartz. South of Baldhead Lake an aeromagnetic high is underlain by gabbroic diorite containing up to 60 percent hornblende with common pyrite and magnetite mineralization.

The southern part of the Bridgeman Lake Pluton lies in the map area. This weakly foliated leucocratic rock, described as an albite granite by Padgham (1960, 1963), is locally porphyritic, containing feldspar phenocrysts up to 5 mm long. A fine- to medium-grained amphibolite, averaging 200 m wide in the map area, encircles the pluton. The outer contact of the amphibolite is with fine-grained hornblendic granodiorite which in turn grades into medium-grained porphyritic granodiorite away from the contact. Areas of medium-grained biotitic granite are also present in this region.

On the southeast edge of the map area, a portion of the Jepson Lake granite is exposed along the northwest shore of Freda Lake. These fine- to medium-grained pinkish-orange cataclastic border rocks contain well-stretched quartz grains and local epidote stringers.

Other intrusive rocks in the map area range in composition from gabbro to coarse-grained granitic pegmatite. Medium-grained massive gabbro, which contains up to 80 percent mafic minerals, forms small plugs and sill-like bodies. Most of these dark green to black rocks occur sporadically from the southeast shore of Contact Lake northeast through Preview Lake to a narrow elongate body between Hebden and Freestone Lakes. Mahon Lake is rimmed by gabbro and may be underlain by a recessively weathered gabbroic plug.

Diorite and granodiorite are rarely found outside the Little Deer Pluton.

Two bodies of quartz-eye granite have been mapped. The largest of these is located west of Ramsland Lake, where irregular to rounded quartz grains reach 3 to 5 mm in diameter. This fine- to medium-grained granite contains up to 5 percent biotite and local muscovite. A north-trending fault through West Ramsland Lake marks the eastern limit of these moderately foliated to schistose rocks. West of Little Deer Lake, another quartz-eye granite forms a stock which may be related to the Little Deer Pluton. Here the rocks have well-rodded oval-shaped quartz grains in a pinkish-grey fine-grained leucogranite groundmass.

Feldspar porphyry occurs throughout the area, usually as small isolated outcrops. These grey fine- to medium-grained felsic rocks containing feldspar phenocrysts up to 5 mm long are probably volcanic-related high-level dykes, although a few may be extrusive.

A large mass of coarse- to very coarse grained granite pegmatite northwest of Hebden Lake contains muscovite books up to 7 cm long and irregularly shaped quartz masses commonly as much as 100 cm in diameter. Pegmatitic masses and narrow discordant to semiconcordant dykes are common in the meta-arkose northeast of Hebden Lake.

Aplitic granite occurs in a few small masses and dykes in the vicinity of Ramsland Lakes, but elswhere is rare. These pinkish-orange very fine grained to aphanitic rocks locally contain xenoliths of the surrounding country rock.

## Structure

Primary volcanic and sedimentary features are rarely present in the map area. Graded bedding in metasediments and pyroclastics, and one occurrence of pillows were, however, used to help determine way up. Throughout the area, supracrustal primary layering ($S_0$) is paralleled by tectonic schistose foliation ($S_1$) with a dominant north to northeast strike. Deformation and shearing typically masks any small-scale primary structures that may have been present.

Large-scale regional folds ($D_1$) have produced synforms and antiforms. There is a large southwesterly-plunging synform near Ramsland Lakes. North of this a southwesterly-plunging antiform has an axial trace passing through Mullock Lake and Heyer Bay west of the map area. The meta-arkose outcrop east of Hebden Lake forms a large slightly overturned synform, and may be an infolded outlier of the McLennan Group meta-arkose (Lewry and Slimmon, 1985).

Down-dip linear stetching is associated with strong mineral and clast lineations. West of Hebden Lake these lineations dip moderately to the west, while southeast of Hebden Lake they plunge steeply to the southeast. This $D_2$ lineation is accompanied by refolding of $D_1$ folds on similar attitudes. Local small-scale kink folds on a dominant east-west axis are considered to be associated with $D_3$.

Cataclastic rocks occur along three main zones in the map area:

1) Along the northern margin of the Little Deer Pluton there are mylonitic crush breccias to protomylonitic rocks with local epidote stringers and lenses.

2) Along the west shore of Hebden Lake is a zone of very fine grained to aphanitic mylonitic rocks containing numerous epidote stringers plus pegmatite and quartz veins.

3) A zone of cataclasis, trending northeast along Freestone Lake to Preview Lake, contains mylonitic feldspar augen crush breccia as well as protomylonitic rocks.

Late brittle fracturing and faulting are present in a series of north- to northeast-trending shear zones and regional lineaments. The Little Deer Pluton is cut by several subconcentric shears with a dominant northwesterly trend.

## Metamorphism

Regional upper greenschist to lower amphibolite facies metamorphism has affected all rocks in the map area. Typomorphic minerals in the area include muscovite, chlorite, biotite, hornblende, actinolite-tremolite, garnet, diopside and andulusite. Metamorphic grade increases slightly to the northeast around Warnock Lake. Retrograde metamorphism has produced chlorite and biotite along some faults and shear zones. Contact metamorphism may have affected the amphibolite rim around the Bridgeman Lake granite, increasing its grainsize and forming garnet.

## Economic Geology

Since the 1930's the region has experienced sporadic periods of exploration activity, primarily in the search for gold. Since the late 1970's this search has intensified with the increase in gold price. Several mineralized zones have been identified in the area through past exploration operations. The history and development of these zones are available in Beck (1959), Forsythe (1971) and Coombe (1984). Numbers in parentheses after the occurrence names correspond to locations on Fig. 1.

### Ramsland Showings (1)

The greatest amount of activity in the map area has been carried out by the Saskatchewan Mining Development Corporation in the Ramsland Lakes area where four main zones of gold mineralization occur.

The Ramsland 'centre showing' (1a) is the most significant occurrence and in 1985 several holes were drilled in the area, with the two best assaying 0.48 oz./ton Au over 11.5 feet and 0.22 oz./ton Au over 9.8 feet (Northern Miner, 1986). The area comprises felsic to mafic metavolcanics and intercalated metasediments that are deformed by three phases of folding. Calcareous sediments containing visible gold are one of three types of mineralized host rocks in the area. Gold is also associated with shear zones in pyrite-bearing intermediate metavolcanics and, in one instance, occurs along the contact of a feldspar porphyry (Forsythe, 1971; Assessment Files[1] 73P07-0071, -0072, -0073, -0113, -0141, -0143; SMDI[2] 73P07-NW Au-16).

The Ramsland 'north showing' (1b) consists of pyrite and native gold mineralization associated with fracture-filled quartz veins in sericitized felsic metatuffs interlayered with felsic agglomerates

[1]Saskatchewan Energy and Mines, Regina.
[2]Saskatchewan Mineral Deposits Index, Saskatchewan Energy and Mines, Regina.

(Forsythe, 1971; Assessment Files 73P07-0071, -0072, -0073, -0113, -0141, -0143; SMDI 73P07-W Au-15).

The Ramsland 'east showing' (1c) consists of a highly fractured granite which contains pyrite, chalcopyrite and gold mineralization associated with quartz-veining and fracture-filling (Forsythe, 1971; Assessment Files 73P07-0071, -0072, -0073, -0113, -0141, -0143; SMDI 73P07-NW Au-17).

The Ramsland 'south showing' (1d) contains pyrite mineralization associated with quartz veins and lenses in felsic metavolcanics. Trenching revealed 0.39 oz./ton Au and 0.38 oz./ton Ag, and a grab sample from a quartz vein assayed 0.96 oz./ton Au (Forsythe, 1971; Assessment Files 73P07-0071, -0072, -0073, -0113, -0141, -0143; SMDI 73P07-NW Au-18).

### Preview North Zone (2)

The only gold produced in the map area was from this zone, where one gold bar was poured by Preview Mines Limited in 1941. This zone occurs along sheared feldspar porphyry which forms the contact between a gabbroic sill to the northwest and metagreywacke to the southeast. Pyrite, arsenopyrite and rare chalcopyrite are present as disseminations and veinlets in quartz veins and in the surrounding country rocks. Quartz occurs as folded, rodded and boudinaged veins and as later fracture fillings. Calcite is present locally in association with the quartz and as separate veins. Mineralization is related to the quartz veins and occurs in two northeasterly-plunging en echelon zones containing a potential of 250 tons per vertical foot at a grade of 0.35 oz/ton Au (Forsythe, 1971; Assessment Files 73P07-0009, -0010, -0021, -0056, -0121; SMDI 73P07-NW Au-1).

### Preview South (PAP C) Zone (3)

This zone consists of subconcordant quartz veins in a variably sheared gabbroic sill. Mineralization comprises arsenopyrite, pyrite and pyrrhotite in the quartz veins and adjacent wall rocks. Trenching results indicate a potential of 130 tons per vertical foot at 0.5 oz./ton Au (Forsythe, 1971; Coombe, 1984; Assessment Files 73P07-0009, -0010, -0021, -0056, -0121; SMDI 73P07-NW Au-1).

### Preview Lake - Joe Showing (4)

Pyrite, arsenopyrite and minor pyrrhotite mineralization occurs in felsic metavolcanics and intercalated metagreywackes. Disseminations and veinlets of mineralization are associated with the numerous concordant quartz veins and lenses present in the rocks, as well as in the country rock. Grab samples returned assays up to 0.58 oz./ton Au (Forsythe, 1971; Assessment Files 73P07-0009, -0024; SMDI 73P07-NW Au-7).

### North Contact Lake Showing (5)

Pyrite, chalcopyrite and rare galena and sphalerite mineralization is associated with fracture-filled quartz veins in intermediate metavolcanics. In addition to gold mineralization, sporadic lead, copper, zinc and nickel values are present (Forsythe, 1971; Assessment Files 73P07-0071, -0073, -0113, -0141, -0143).

### Socko-Tyon Showing (6)

Trenching has exposed a feldspar porphyry intrusion in contact with intermediate metavolcanics to the west along a sheared contact. Pyrite, pyrrhotite, arsenopyrite and rare galena and sphalerite mineralization occurs in the country rock, but is primarily associated with fracture-filled quartz veins subconcordant to the shear zone in the intrusion. Assay results are unimpressive from this zone; one grab sample returned 0.01 oz./ton Au (Forsythe, 1971; Assessment Files 73P07-0076, -0139; SMDI 73P07-NW Au-13).

### Upises Lake Showing (7)

This zone consists of intermediate to mafic metavolcanics containing metagreywacke intercalations and areas of intrusive granite related to the Little Deer Pluton. Northeast- and northwest-trending shear zones cut the rocks and contain numerous fracture-filled quartz veins. Pyrite, pyrrhotite, chalcopyrite, galena and visible gold mineralization is mainly associated with the quartz veins but also occurs in the country rock. Trenching yielded assays up to 11.79 oz./ton Au and 2.6 oz./ton Ag (Forsythe, 1971; Coombe, 1984; Assessment Files 73P07-0078, -0128, -0130, -0144; SMDI 73P07-NW Au-12).

### Teneycke Lake Showing (8)

Chalcopyrite mineralization occurs in a skarn located along the contact of Little Deer Pluton dioritic rocks. In this area the diorite intrudes calc-silicates and metagreywackes. Trench samples assayed 0.17 oz./ton Au, 0.53 oz./ton Ag and 0.31 percent Cu (Assessment Files 73P07-0128, -0130, -0138, -0144; SMDI 73P07-NW Au-14).

### Other Mineralization

In addition to gold mineralization, the area contains several sulphide-rich zones, some containing elevated copper values, which occur in a variety of rock types but are characteristically associated with quartz veins and shear zones. Southeast of Hebden Lake, several sulphide-rich gossans are located along EM conductors which primarily occur along concordant shears in metagreywackes that are closely associated with metavolcanics. Many of these zones are potentially gold-bearing and warrant further inspection.

One such zone occurs on the northeast shore of the small bay located 0.5 km from the northeastern extent of Freestone Lake where metagreywacke is in contact with feldspar porphyry and intermediate metavolcanics. Disseminated pyrite and chalcopyrite mineralization is associated with shearing and quartz-veining in these rocks. The narrow gabbroic body that stretches between Hebden and Freestone Lakes contains local pyrite mineralization and elevated Ni and As values.

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Project 8624A

# Bedrock Geological Mapping, MacKay Lake North (Part of NTS 73P-7)

by John F. Lewry[1]

Lewry, J.F. (1986): Bedrock geological mapping, MacKay Lake North; in Summary of Investigations 1986, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 86-4.

This work is a small component of 1:20,000 scale remapping in the La Ronge Domain. The area was specifically chosen to address several current problems of geological evolution of the La Ronge Domain, including the relative age of the La Ronge Group metavolcanics and the MacLennan group meta-arkoses, the nature of the southern extension of the Haugen Lake Synform (Abraham, 1985) and the possible southward continuation of documented high-strain zones bounding the MacLennan Group farther north (Abraham, 1985; Thomas, 1984, 1985).

Two supracrustal assemblages have been distinguished this summer in the MacKay Lake area. A "Volcanic Assemblage", part of the La Ronge Group, is intruded by subconcordant quartz-phyric leucogranite sheets. An "Arkosic Assemblage", which may represent the basal part of the MacLennan Group, incorporates clastic detritus derived from both the Volcanic Assemblage and leucogranite, and stratigraphically overlies both, probably over a landscape unconformity. Several late- to post-kinematic quartz diorite-granodiorite plutons also occur. Figure 1 shows an outline of the geology.

## Volcanic Assemblage

Mixed volcanic and volcanogenic rocks of the La Ronge Group occur mainly in the west and south, and adjacent to Highway 102 in the extreme east. Outcrop is generally limited and of poor quality; contacts between rock units were nowhere observed. The assemblage is affected by extremely heterogeneous strain, and protoliths of the most highly deformed components are uncertain. Detailed subdivision and extrapolation of internal lithological boundaries are therefore generally unwarranted and of doubtful validity at the scale of mapping undertaken.

Much of the volcanic Assemblage comprises coarse heterolithic fragmental rocks. The most extensive type, interpreted as polymictic volcanogenic metaconglomerate, incorporates varied fine-grained felsic to mafic volcanic and subordinate granitoid clasts, typically up to about 15 cm in maximum dimension. The matrix is generally a very inequigranular biotitic and locally hornblendic metagreywacke but locally grades into a more mafic finely fragmental hornblendic gneiss. Primary features are obscured by strain but most large clasts appear to have been well rounded and the rock generally seems to have been clast supported.

Subordinate coarse fragmental units, including some immediately west of the highway and those exposed in lakeshore outcrop in the extreme west, have a very mafic amphibolitic matrix and more angular, lithologically less varied clasts. Some of these may represent tuff breccias and volcanic agglomerates.

A distinctive feldspar-phyric trachytoid mafic gneiss forms prominent, widely distributed units in the volcanic assemblage. Where least deformed, it contains abundant elongate-tabular subhedral to euhedral feldspar laths 0.5 cm to over 6.0 cm in length in a fine-grained mafic matrix. The feldspars typically define a variably well-developed trachytoid flow orientation. With increasing strain, such rocks pass into intensely foliated feldspar-augen gneisses and thence into fine-grained dark grey laminated and 'beaded-feldspar' gneisses which locally display a mylonitic fabric. Some of the more highly strained variants of this rock were included in Forsythe's (1968) Unit 7. In outcrops immediately west of the highway, some less deformed variants appear coarsely fragmental and may represent flow top breccias. Generally, however, it is unclear whether the trachytoid units are flows or intrusive sheets.

Undifferentiated mafic to intermediate members include mafic gneisses with abundant small lensoid feldspar megacrysts, tentatively interpreted as porphyritic flows, medium- to fine-grained 'metabasalts' or 'metadiabases', strongly foliated fine-grained amphibolites, and mafic to felsic hornblende or hornblende-biotite schists which may variously be deformed flows, tuffs or volcanogenic metasediments. In rare clean outcrops, some of the rocks are evidently tuffs and tuff breccias. Local fine-grained grey to pink leucocratic felsic intercalations in the Volcanic Assemblage may be volcanics or intensely strained to mylonitic intrusive sheets.

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Project supported in part by contract, with funds provided under the Saskatchewan component of the Canada-Saskatchewan Subsidiary Agreement on Mineral Development, 1984-89.

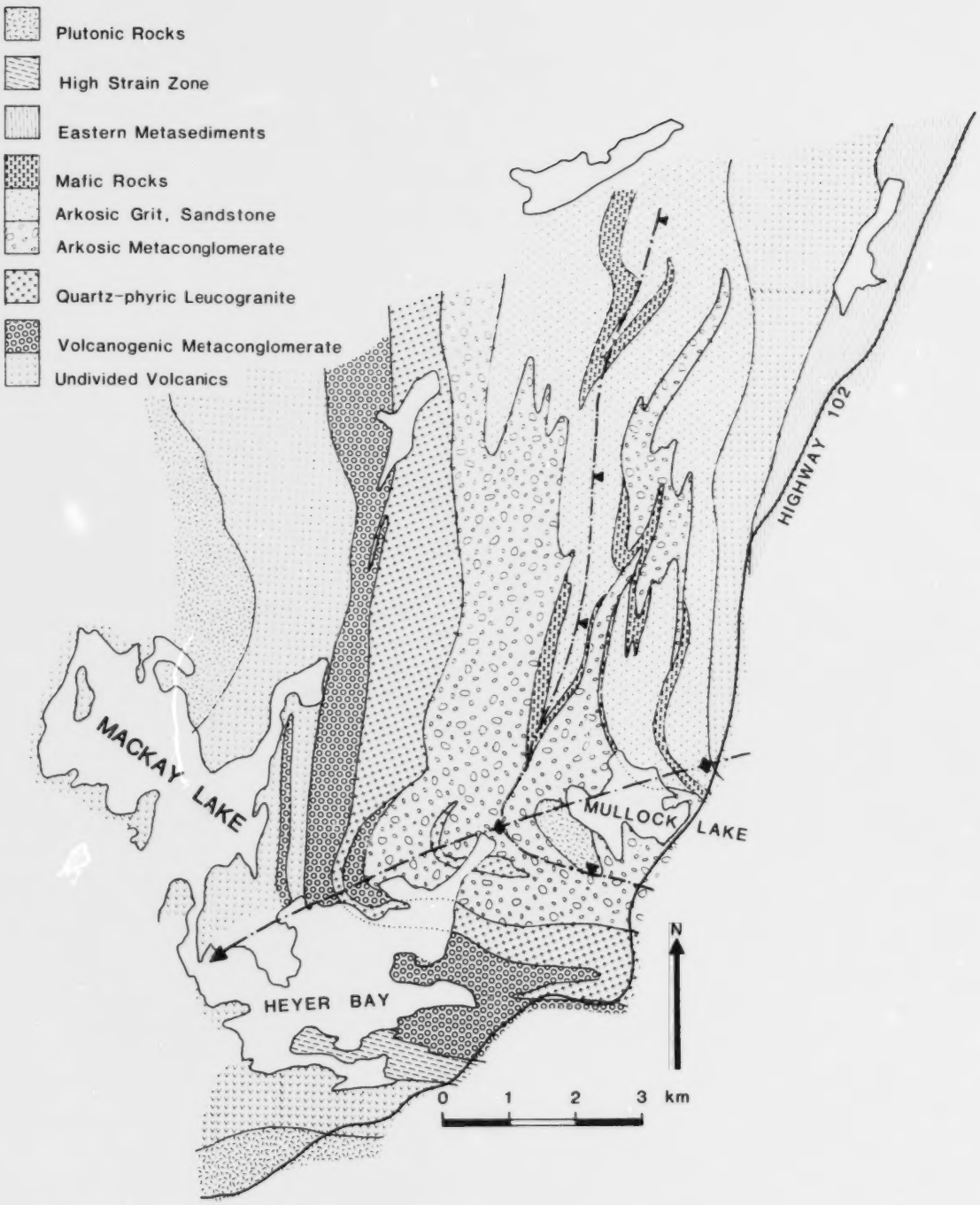


Figure 1 - General geology of the MacKay Lake North

Quartz-porphyritic Leucogranite

This unit forms a major subconcordant sheet (or possibly sheets?) lying between the Volcanic and Arkosic Assemblages north and east of Heyer Bay, and also occurs as isolated smaller bodies elsewhere. Abundant rounded to ovoidal grey-white quartz megacrysts, generally up to 1 cm across, occur in a finer grained red-pink quartz-feldspar matrix which locally contains up to 5 percent biotite. Subordinate pink potassium feldspar megacrysts occur locally. The leucogranite is interpreted as a high-level intrusive on the basis of extreme uniformity, inconclusive evidence of intrusive contact with the Volcanic Assemblage, absence of included pebbles or other persuasive evidence of clastic derivation and, most convincingly, the occurrence of abundant pebbles and cobbles of this rock type in adjacent arkosic metaconglomerates to the north and east of its main outcrop areas. The 'porpnyritic' fabric may be partly a function of deformation rather than a reflection of primary texture: weakly deformed cobbles and boulders of what is evidently the same rock type, occurring in adjacent arkosic metaconglomerates, are coarser grained with quartz megacrysts only slightly larger than general grain size.

Arkosic Assemblage

This assemblage comprises immature arkosic boulder, cobble and pebble metaconglomerates, and associated finer grained felsic rocks interpreted as pebbly meta-arkosic quartz grits, sandstones and silts.

Arkosic metaconglomerates and pebbly arkosic grits are the most abundant rock types. The metaconglomerates are generally clast supported. Clasts typically range from a few to about ten centimetres in size. In places, notably near contacts with quartz-phyric leucogranite, larger cobbles and boulders up to about 0.5 by 1 m are abundant, and boulders up to 1 by 2 m were observed locally. The clasts are generally well rounded and mostly comprise locally derived quartz-phyric leucogranite. Pebbles and cobbles of other granitoid rocks and of fine-grained felsic and mafic volcanics, including the distinctive 'trachytoid' feldspar-phyric rock, are generally subordinate but occur abundantly in some local but generally thin units. The pebbles and cobbles occur within an arkosic, grey to pink, streaky-inhomogeneous, gneissose to schistose, highly inequigranular matrix which also incorporates plentiful small round to lensoid quartz grit clasts. Variable but generally minor amounts of biotite and local hornblende are included, and in places the matrix is a muscovite-rich schist. In many areas, conglomerate clasts are clearly seen only in very small clean outcrop surfaces and in the more prevalent lichen-covered outcrops are indicated only by general 'ribby' or irregular surfaces.

On this basis, the author felt justified in including within the arkosic metaconglomerate unit many poorly exposed zones, including some areas mapped by Forsythe (1968) as Unit 7, which are typified by streaky heterogeneous micaceous felsic gneisses in which definite large clasts could not be documented with confidence.

The coarsest arkosic pebble and cobble metaconglomerates generally occur in the west and southwest, close to the sheets of quartz-phyric leucogranite. In the east, rocks included in this unit tend to be finer grained and either grade into or are interdigitated with arkosic grits.

The arkosic metaconglomerates differ markedly in character, general lithological association and probable paleoenvironment from the more heterolithic volcanogenic metaconglomerates assigned to the Volcanic Assemblage. Both were included as components of Forsythe's (1968) Unit 11.

Units interpreted as quartz-eye arkosic and sandstones are similar in appearance to the quartz-phyric leucogranite, from which they are thought to be largely derived. They were distinguished primarily on the basis of local inclusions of granitic and fine-grained felsic clasts up to several centimetres in maximum length, local indications of compositional layering, and other generally ambiguous mesoscopic and macroscopic evidence of clastic sedimentary origin, such as apparent large-scale interdigitation with arkosic conglomerate. Nevertheless, the relative exent of the two rock types in the eastern part of the area is uncertain.

Pink felsites are a major component of the Arkosic Assemblage. Typically, they are uniform featureless highly leucocratic medium- to fine-grained reddish, salmon pink or grey-pink felsic rocks with a strong regular flaggy or schistose foliation. Biotite is absent or only a minor constituent. More schistose variants are commonly muscovitic. Small sparse rounded to highly lensoid grey quartz 'eyes' occur sporadically throughout the unit, and locally there appears to be gradation into the quartz-eye grits. Individual small leucogranite or fine-grained felsic clasts can be distinguished locally in thin conglomeratic seams.

Most, if not all, of the felsites included within the Arkosic Assemblage are interpreted as arkosic sandstones or silts on the basis of their association, apparent local gradation into and interlayering with the quartz-eye grits and arkosic metaconglomerates, the local inclusion of small pebbles, and the indefinite indications of compositional banding. No felsic volcanic features were seen. Some of the felsites may be strained equivalents of the quartz-eye grits and pebbly grits.

Other Rocks of the Arkosic Assemblage: Locally, where the contact zone between the quartz-phyric leucogranite and arkosic metaconglomerates is

well exposed, rocks thought to represent a weathering profile with overlying granite-wash regolith occur. Such relations were best seen along the contact about 400 m west of the highway, south of Mullock Lake. At about 10 m from the contact in this locality, the normally uniform leucogranite is less homogenous in fabric, with development of irregular ill-defined anastomosing zones of greyer more schistose quartz-phyric material surrounding more normal lineated although unfoliated pink leucogranite. Closer to the contact, there is gradation into a zone of indefinitely bounded subangular to rounded blocks of leucogranite in a grey muscovite-rich intensly foliated selvage. This is succeeded by arkosic conglomerate containing discrete subangular to subrounded pebbles and cobbles of leucogranite up to 30 cm across in a coarse gritty strongly foliated granite wash matrix. Similar, but less convincing, evidence of erosional unconformity and weathering of the leucogranite was seen in other localities at the eastern margin of the leucogranite north of Heyer Bay.

Rocks of more enigmatic character and derivation occur just north of Heyer Bay, near the eastern boundary of the main quartz-phyric leucogranite sheet at its narrowest point. These include:

1) Fine-grained uniform garnetiferous pink 'felsite'.

2) Medium- to fine-grained, mid- to dark grey garnetiferous biotite 'psammites' incorporating irregular zones and patches of coarser 'dioritic' hornblende-plagioclase gneiss. Locally, the 'dioritic' material appears to vein the psammite. Garnets are up to 1 cm across, generally pink in colour and commonly surrounded by prominent feldspar-rich depletion haloes.

3) A fine-grained creamy-white sparsely garnetiferous and coarsely rubbly/fragmental rock with sporadic patches rich in quartz 'eyes', which includes abundant small lensoid to angular fine-grained biotitic schist fragments, and larger blocks of buff-white beaded-quartz schist. Locally, rubbly fragments are enclosed in a selvage of grey schistose material.

4) Fine-grained pinkish-brwon felsic gneisses, locally containing small pink feldspar lenses (possibly clasts).

5) Finely layered rocks comprising creamy leucocratic units with small mafic fragments, dark-grey garnet 'psammite', and fine grey siliceous schists containing fine-grained creamy lenses. The latter are tentatively interpreted as clasts but may be sillimanite-quartz faserkiesel.

Locally, near the contact with the leucogranite, this assemblage is transected by mylonitic zones.

In view of location, and in light of other evidence that the contact of the leucogranite with arkosic metaconglomerates represents an unconformity, this assemblage is tentatively interpreted as a mixture of highly weathered and variably strained granite wash and regolithic material, possibly with intercalated fluvial sediments. The 'dioritic' patches and segregations may derive from local calc-silicate lenses. Alternatively, part of the assemblage may be derived from felsic volcanics.

Subordinate mafic rocks of varying character occur as intercalations within the Arkosic Assemblage. Most are medium- to fine-grained 'microdiorite', metadiabase or foliated amphibolite with few distinguishing features, but some belts comprise feldspar-phyric trachytoid gneiss or include coarsely fragmental rock types, interpreted as either volcanogenic metaconglomerate or agglomerate. Some of these rocks may be minor intrusive sheets, but others may have originated by 1) minor volcanic activity during deposition of the Arkosic Assemblage, 2) tectonic intercalation, either as early fold closures or thrust slivers, or 3) exposure of paleotopographic ridges in a landscape unconformity beneath the Arkosic Assemblage.

A mixed assemblage of leucocratic pink felsic gneisses tentatively interpreted as meta-arkoses, biotite or hornblende-biotite metagreywackes, polymictic metaconglomerates and minor amphibolitic gneisses occur in the northeastern part of the area, adjacent to Highway 102. The relation of these 'Eastern Metasediments' to other supracrustal rocks was undefined. They are presumably equivalent to the Otter Lake gneisses of the MacLean Lake Belt (Abraham, 1985).

Highly Strained Rocks of Uncertain Origin

An east-trending belt extending through the southern part of Heyer bay is generally more highly strained than elsewhere. The central most highly strained zone has uncertain portoliths. Most rocks in this zone are very fine grained 'cherty' grey-white to pink and have a regular flaggy to schistose and locally mylonitic foliation. Subordinate dark grey to black fine-grained mafic schists and gneisses of unknown lateral continuity also occur. Some units display an ill-defined lenticular heterogeneity, locally contain identifiable but extremely flattened clasts and are tentatively interpreted as strained volanogenic metaconglomerates. Some thin pink felsite units contain plentiful small lensoid quartz augen and may be mylonitized quartz-phyric leucogranite. Other, dark grey 'beaded-feldspar' gneisses might derive from trachytoid feldspar-phyric flows or intrusives. The remainder may be either highly strained felsic volcanics or metasediments. Regardless of protoliths, these rocks represent a well-defined ductile high strain zone. Narrow zones of later more brittle shearing and cataclasis also occur locally within the belt.

Plutonic Rocks

Unfoliated or weakly foliated coarse-grained mesocratic hornblende or hornblende-biotite quartz diorite to granodiorite occurs in the extreme south and northwest, comprising parts of the Little Deer and Bartlett Lake plutonic complexes respectively. Lack of significant tectonic fabric suggests that they are late- to post-kinematic plutonic. In contrast, medium- to coarse-grained mesocratic biotite quartz diorite-granodiorite exposed in limited outcrops immediately southwest of Mullock Lake posseses a strong penetrative linear fabric and generally a less pronounced foliation. The extent and contact relations of this body are undefined but it is certainly plutonic, rather than volcanic as implied by Forsythe (1968).

Massive red-pink granite pegmatite occurs sporadically throughout the area, forming major bodies near the eastern and southern parts of Mullock Lake and on the north shore of Heyer bay, where they lie near the hinge of the Mullock Lake Antiform, described below.

Lithostratigraphy and Age Relations

Features described above unequivocally demonstrate that the Arkosic Assemblage is younger than both the Volcanic Assemblage and the quartz-phyric leucogranite, and stratigraphically overlies them with marked erosional unconformity. The abrupt decrease in thickness of the main quartz-phyric granite sheet just north of Heyer Bay is provisionally interpreted as a paleo-erosional feature rather than a function of original thickness or later strain attenuation, and may represent a paleoscarp. More speculatively, the smaller bodies of quartz-phyric granite exposed on either side of the northeast arm of Heyer Bay may reflect erosional intersection of a small hill in the exhumed landscape.

Present mapping did not extend far enough northwards for relations between the presently described Arkosic Assemblage and the main belt of the MacLennan Group to be established. From previous mapping (Padgham, 1960; Abraham, 1985), however, the Arkosic Assemblage probably represents either a conformable basal portion of the MacLennan Group or is separated from it by another unconformity. In either case, relations seen in the MacKay Lake area strongly suggest that the MacLennan Group is younger than the La Ronge Volcanic Group.

Structural Geology

Most rocks in the area possess a variable weak to intense and locally mylonitic kinematic foliation parallel or subparallel to transposed lithological layering. This is commonly accompanied by a moderate to steep southwest- to west-plunging linear fabric lying within the foliation. Linear fabric elements include preferred orientation of long axes of triaxially deformed pebbles, mineral lineation and gneissic subdomain streaking. In unlayered uniform rock types such as the quartz-phyric leucogranite the linear fabric is generally dominant and foliation weak or absent. Few minor folds were observed.

Lithological layering and dominant foliation are deformed about a moderately to steeply southwest-plunging upright antiform, here termed the Mullock Lake Antiform. A complementary major synform occurs to the southeast (Slimmon, this volume). Dominant linear fabrics are broadly co-axial with this major fold and are thought to be of the same age. Locally, lineation is accompanied by a weakly developed subvertical southwest-trending secondary foliation which may also be coeval with the development of the Mullock Lake Antiform.

Southward continuation of the closure of the Haugen Lake Synform (Abraham, 1985) is ill defined. However, documented field relationships demonstrate that the Arkosic Assemblage is stratigraphically younger than the metavolcanic and volcanogenic rocks on either side of it. Moreover, aeromagnetic trends suggest possible major closure north of Mullock Lake, and outcrop pattern of units within the Arkosic Series suggest the presence of complex tight to isoclinal fold closures which are axial planar to the dominant foliation direction. These data suggest that the Arkosic Assemblage occupies the complex core of an overturned major synform representing the southerly continuation of the Haugen Lake structure, and that this is refolded about the Mullock Lake Antiform. Dominant foliation in the area is thought to be axial planar to and coeval with this early major fold, save possibly in the northern part of the area. Mapping by Slimmon (this volume) suggests that the Arkosic Assemblage terminates within the hinge zone of this structure not far east of the highway.

There is no obvious southerly extension of either the MacLennan Lake Tectonic Zone (Thomas, 1984, 1985) or the Stewart River Shear Zone (Abraham, 1985) into the MacKay Lake area. Regional structural considerations suggest that the high strain belt running through south Heyer Bay should turn northwards, around the nose of the Mullock Lake Antiform, but this could not be documented: submylonitic to mylonitic fabrics were seen locally in the Volcanic Assemblage north of MacKay Lake but no coherent major high strain zone was defined. Narrow high strain zones are present within the quartz-phyric leucogranite and arkosic metaconglomerate and locally at the contact of these units north of Heyer Bay. Thus, the MacLennan Lake Tectonic Zone may dissipate southwards; in view of poor outcrop quality in critical areas, however, this is not firmly established.

Parts of the volcanic assemblage adjacent to Highway 102 are highly strained, but southward continuation of the Stewart River Shear Zone of Abraham (1985) as a coherent entity was not observed. Such continuation may, however, lie east of the area covered by present mapping.

## Economic Geology

Subeconomic gold mineralization of the Eureka showing (Coombe, 1984) occurs within the belt of highly strained to mylonitic rocks extending through the peninsula in the southern part of Heyer Bay. Such coincidence of mineralization with zones of high ductile to brittle strain is common to most gold occurrences in the La Ronge Domain, implying predominant structural, rather than lithostratigraphic, control of mineralization (Coombe et al., 1986).

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Project 8609A

# Bedrock Geological Mapping, MacKay Lake South (Part of NTS 73P-7)

by M.W. Thomas[1]

Thomas, M.W. (1986): Bedrock geological mapping, MacKay Lake South (part of NTS 73P-7W); in Summary of Investigations 1986, Saskatchewan Geological Survey; Saskatchewn Energy and Mines, Miscellaneous Report 86-4.

This summer a 40 km$^2$ area termed the MacKay Lake South area was geologically mapped at a scale of 1:20,000 (Fig. 1). The work forms part of the 1:20,000 scale revision mapping by the Saskatchewan Geological Survey of the Central Metavolcanic Belt in the La Ronge Domain, and in particular of the Sulphide Lake area (see also separate reports by Sibbald, Slimmon and Lewry, this volume).

Situated 35 km north of La Ronge, access to the MacKay Lake South area is easily attained via Highway 102. There are also all-weather trails from the highway to both MacKay and Five Fingers Lakes, the only lakes of any size within the area. Physiographically, the region is typical of much of the Saskatchewan Shield, with more or less abundant bedrock uplands and ridges separated by muskegs, bogs and streams. Relief nowhere exceeds 25 m. Pleistocene glacial cover is common but generally thin, except along the highway and around MacKay Lake where thick sand and boulder deposits effectively obscure the bedrock.

The Geological Survey of Canada undertook early geological investigations in the vicinity, including reconnaissance 1 inch to 4 mile mapping in 1935 (McLarty, 1936) and 1 inch to 1 mile mapping in 1938 (Keith, 1941). In the sixties, with increasing interest in the economic mineral potential of the La Ronge area, the Saskatchewan Department of Mineral Resources undertook detailed geological investigations that resulted in a 1 inch to 2 mile geological map and comprehensive report of known mineral occurrences (Forsythe, 1968, 1971). Recently, the entire La Ronge area (NTS 73P) has been geologically reviewed and compiled at 1:250,000 scale (Lewry and Slimmon, 1985).

Beginning in 1926, reports of gold from rocks north of Lac la Ronge generated considerable prospecting, trenching and minor development work in the region, particularly in the Sulphide Lake area (Coombe, 1984). However, until recently, most documented mineral exploration in the MacKay Lake South area itself has been directed towards locating stratabound sulphide occurrences similar to the Cu-Au-Ag Anglo-Rouyn property north of Lac la Ronge (Forsythe, 1971). In this regard, various mag/EM surveys, trenching and minor diamond-drilling have been conducted in supracrustal rocks at Five Fingers Lake and southwest of Little Deer Lake. In the past few years, gold exploration in the entire La Ronge Domain has reached unprecedented levels. At present, the entire MacKay Lake South area is held under mineral disposition and gold exploration is ongoing.

Precambrian rocks in the MacKay Lake South area have undergone polyphase deformation and metamorphism and are probably Lower Proterozoic in age (Van Schmus et al., 1985). They are broadly divisible into psammitic/psammopelitic 'metagreywackes' of probable turbidite affinities, intermixed felsic to mafic metavolcanic and volcaniclastic metasedimentary rocks, and felsic to ultramafic igneous rocks intrusive into the supracrustals (Fig. 1). Basement to the supracrustal rocks was not identified. With reference to the recent regional compilation of the La Ronge area by Lewry and Slimmon (1985), the 'metagreywackes' would comprise part of the "Crew Lake Belt" and the metavolcanic/volcaniclastic and intrusive rocks may correlate with similar rocks of the "Central Metavolcanic Belt" to the north.

## Supracrustal Rocks

Monotonous interbanded psammitic/psammopelitic 'metagreywackes' (unit GK) are exposed in the central part of the area (Fig. 1). The unit is typified by light grey, fine-grained and sharply bounded psammite bands, ranging in thickness from 2 cm to greater than 2 m, occurring amongst dark grey to brown very fine grained schistose psammopelite. The resulting exposures are conspicuously flaggy. In the psammopelites, biotite commonly occurs in 1 by 3 mm aggregates, resulting in a speckled texture. Lozenge-shaped zoned calcareous concretions with hornblende, epidote, garnet and/or calcite are common within some psammitic intervals. In places, psammites are rare and thick sections of speckled biotite schists are exposed. Hornblende-bearing psammitic bands occur sporadically throughout the 'metagreywackes'; garnet is a more rare accessory. On some clean exposures, primary structures

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Project funded under the Saskatchewan component of the Canada-Saskatchewan Subsidiary Agreement on Mineral Development 1984-89.

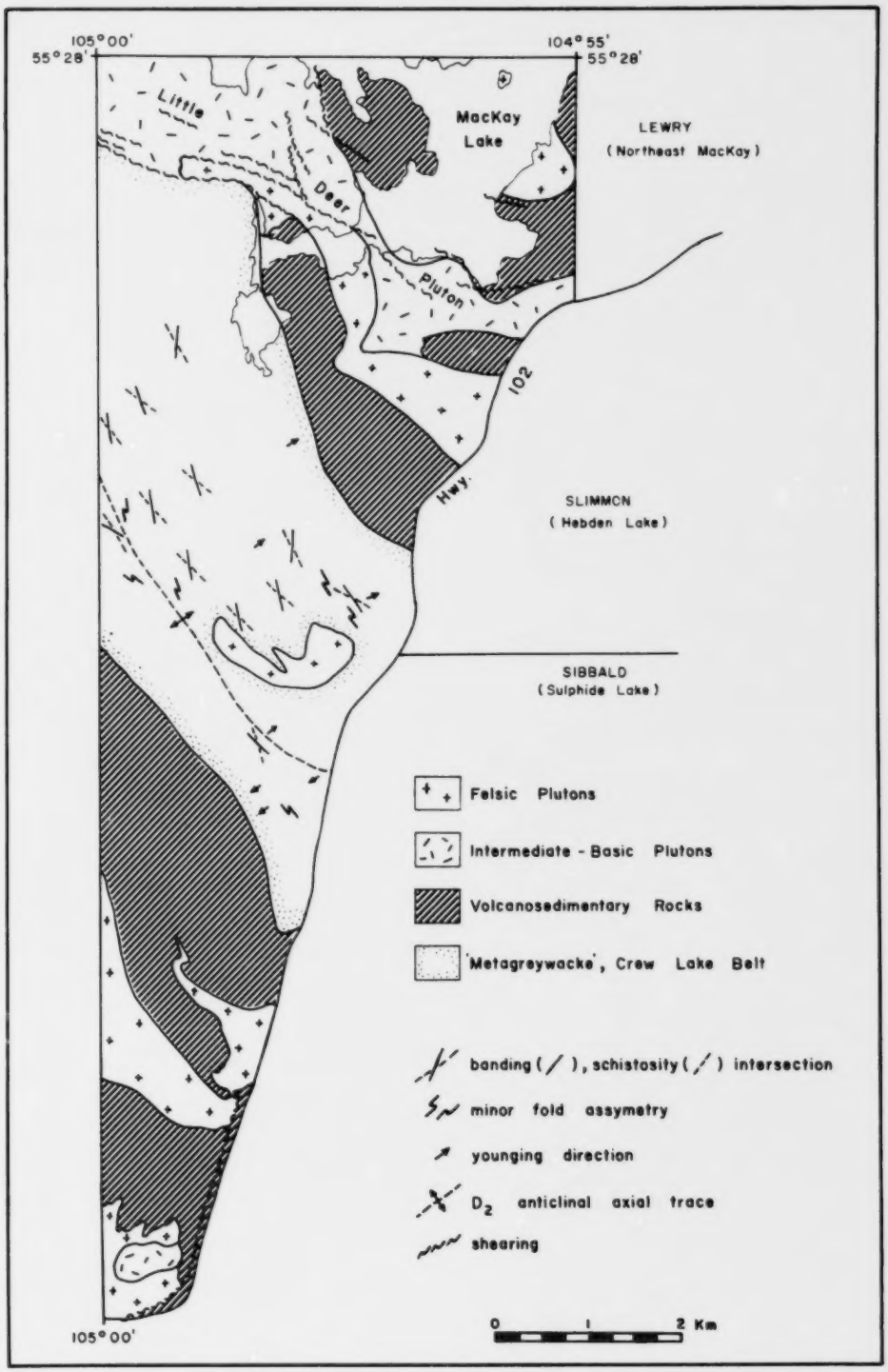


Figure 1 - Location and generalized geology of the Mackay Lake South area.

including parallel laminations, cross laminations and, more commonly, graded bedding were observed. These structures in part typify turbidity current-generated 'Bouma sequences' (Walker, 1979) and, when coupled with the flaggy interbanded nature of the psammites and psammopelites, indicate the possibility of unit GK being a turbidite deposit.

Conformable to locally discordant white quartz and quartzofeldspathic neosome sweats are ubiquitous in this unit. In the northwest, the neosome comprises up to 50 percent of some outcrops and the rocks could properly be called migmatites.

Contacts with adjacent mafic to intermediate schists to the northeast and southwest are gradational over tens of metres, with increasing hornblende content and interbanding of hornblendic and biotitic schists. A conformable sequence is indicated.

Predominantly very fine grained dark psammopelitic biotite wackes (unit Bn) are mainly exposed south of unit GK. They are in many respects similar to the 'metagreywackes', in that they display speckled biotite texture, white quartzofeldspathic neosome, sporadic calcareous concretions, hornblende-bearing layers and scattered garnets. However, psammitic interbands are rare and flaggy compositional banding is not apparent. Less siliceous, very fine grained, black, slaty and locally rusty pyritic rocks are common; diamond-drilling has intersected massive barren sulphide in these rocks (Assessment File 73P07-0103)[1]. Unit Bn in this area also has a strong aeromagnetic/EM signature compared to adjacent rocks (Geological Survey of Canada, 1953). Indeed, the contact between units Bn and GK near Highway 102 is inferred from aeromagnetic contours, since a paucity of outcrop in this area does not permit lithological differentiation of the two units.

Biotite wackes are also exposed northwest of Five Fingers Lake, interleaved with amphibolitic rocks. They are much more common here than indicated on the geological map but are either too thin or too poorly exposed to indicate. Along the shore of MacKay Lake, thin compositionally banded garnet-staurolite(?)-muscovite-bearing psammopelitic to pelitic schists are exposed. Staurolite is restricted to specific layers and occurs in unoriented twinned idioblastic porphyroblasts.

A conspicuous white calcareous meta-arenite (unit S) is exposed in the south. The unit, which is very fine grained, homogeneous, sucrosic/granular textured and generally massive to locally flaggy, contains less than 5 percent muscovite and biotite, with calcite common in lenses, laminae, and interstitially. Grains are well sorted and subangular; an isolated coarser (1 by 0.5 mm) subrounded quartz grain within the very fine grained subangular matrix was observed in one specimen. Because of the fine grain size, relative proportions of quartz and feldspar are difficult to determine. However, the rock appears to be extremely siliceous. Unit S is mainly exposed in a band over 300 m wide and less than 2 km in strike length. An interbanded contact with adjacent rocks was observed over 10 m at one locality.

Mixed metasediments (unit X) are sporadically exposed in the south where they are characterized by thin regular compositional layering and locally abundant fine to very coarse xenoblastic garnet porphyroblasts or garnet-quartz aggregates. Interbanded rock types include garnet±anthophyllite-hornblende-muscovite-bearing psammitic to pelitic schists, flinty garnet-quartz and hornblende-quartz rock (metachert?), garnet±quartz-anthophyllite-hornblende-biotite-muscovite-pyrite schist with garnet blasts comprising up to 50 percent of the rock, and hornblende-blastic amphibolite±chlorite-epidote-biotite-calcite. Compositional bands range in thickness from less than one centimetre to one metre. Excluding porphyroblastic minerals such as garnet, hornblende and anthophyllite, the rocks are very fine grained. Considering the local abundance and iron-rich nature of such minerals as garnet and anthophyllite, the unit probably in part represents a silicate-facies iron formation.

Interbanded felsic to intermediate schists (unit F) comprise grey fine-grained and commonly garnetiferous quartzofeldspathic rocks with hornblende±biotite constituting from 5 to 25 percent of the unit. Epidote, muscovite, diopside and calcite occur locally. In the southeast part of this unit, alternating 10 mm thick hornblendic-biotitic bands are common, and coarser felsic to intermediate variations occur on a tens of metres scale. Towards the northwest, interbanded intermediate hornblendic schists are progressively less common, as is the occurrence of garnet and the centimetre-scale banding, giving way to homogeneous fine-grained felsic schists with less than 15 percent combined hornblende and biotite. In these more homogeneous rocks, sporadic lapilli-sized aphanitic felsic and more rare mafic fragments occur in the quartz-feldspar matrix. One occurrence of possible lapillistone/tuff breccia was observed to contain abundant lensoid felsic fragments up to 3 by 10 cm in a very fine grained intermediate matrix. Fragmental textures are probably more common but identification of unequivocal fragments in the strongly foliated schists is difficult. This problem is compounded by the abundant occurrence of lensoid medium-grained leucocratic quartz-feldspar-hornblende sweaty patches which give the outcrop a "pseudofragmental" texture.

Mafic to intermediate schists (unit M) occur throughout the MacKay Lake South area. The

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mafic rocks are generally dark green to black, very fine grained and homogeneous hornblende-feldspar schists containing from 35 to 60 percent mafic minerals with or without subordinate epidote, biotite and/or calcite. Textural variation from laminated or schisty to hornblende-porphyroblastic over a distance of 5 to 50 m is characteristic; the generally equant hornblende blasts are either xenoblastic and flasered, or idioblastic and unoriented. Paler intermediate amphibolites contain less mafic minerals (15 to 35 percent) and usually some quartz. Alternating schisty to hornblende-blastic textures are again common. These amphibolitic rocks locally display vague fragmental textures possibly representing tuff or flow breccias. In the MacKay Lake and Five Fingers Lake areas, homogeneous feldspar-phyric intermediate and mafic amphibolites possibly represent porphyritic flow rocks. Other than these rarely observed features, primary textures are not evident and have likely been overprinted by the extensive hornblende blastesis.

Thin intercalated hornblende-biotite-bearing psammitic to pelitic schists are generally present in unit M. In the Five Fingers Lake area, these sedimentary schists, as well as banded diopsidic calc-silicate rock (unit C), are especially common, and in many outcrops the mafic to intermediate amphibolites are also compositionally well banded, suggesting some reworking of these rocks. Layering appears to be more pervasive towards the northwest with the increasing abundance of intravolcanic sedimentary material (unit Bn). Transitional hybrid rock compositions and nondiagnostic primary structures and textures make assigning a volcanic or sedimentary parentage to many outcrops in this region difficult if not impossible. The amphibolitic rocks separating unit GK 'metagreywackes' from unit Bn biotite wackes comprise homogeneous to locally fragmental mafic volcanics in the northwest interbanded with progressively more metasedimentary material towards the southeast. The metavolcanics eventually appear to pinch out altogether. Similar complex interfingering of metavolcanics and metasediments has been documented in other parts of the La Ronge Domain and has been inferred to indicate sedimentary reworking of mainly unlithified pyroclastic deposits (Thomas, 1984). This type of facies transition could be applied equally to the lateral changes observed in unit F felsic to intermediate schists described above.

Felsic schists (unit R) are exposed in the northern and southern extremities of the area. In the south they are generally light grey to tan, homogeneous and very fine grained quartzofeldspathic rocks with less than 10 percent finely flecked biotite. Hornblende occurs sporadically in sweaty lenses and in unoriented laths along foliation planes (garbenschiefer). Fine muscovite flakes oblique to foliation, calcite lenses and rare red garnet are also present. The rocks commonly have a somewhat earthy texture, and are spotted with yellowish, round to lensoid aggregates of very fine grained quartz-feldspar 1 to 2 mm in size. As well as defining the foliation, biotite is also commonly lineated and some flecks are lath-shaped, indicating possible pseudomorphing of the biotite after hornblende. A vague centimetre- to metre-scale colour banding is evident on some clean exposures. These southerly felsic schists are extensively intruded by felsic feldspar porphyry sills and dykes (unit Gf) which comprise as much as 50 percent of many outcrops.

In the north around MacKay Lake, medium to dark grey felsic schists are somewhat more mafic than those exposed in the south, containing 5 to 15 percent biotite±hornblende. They are transitional to the intermediate hornblendic schists of unit M in this area. Small idioblastic magnetite grains are characteristic of these rocks and feldspar-phyric textures with round light pink to white feldspars one millimeter in size are present sporadically. Unit R felsic schists are probably derived from fine to coarse ash tuffs and minor crystal tuffs.

## Intrusive Rocks

Bands of dark green, fine- to medium-grained homogeneous ultramafic rocks (unit U) range in thickness from 5 to 20 m and occur almost exclusively associated with mafic to intermediate schists (unit M). Observed contacts with adjacent rocks are sharp and conformable, and the rocks are probably intrusive sills.

Biotite- and muscovite-bearing quartz-eye granite (unit Gq), mainly exposed in the south, characteristically contains unoriented subangular to rounded grey quartz phenocrysts from 1 to 3 mm in diameter distributed irregularly throughout a foliated fine-grained groundmass. Feldspar phenocrysts occur locally. In places the rock displays a coarse sheeted banding marked by micaceous laminations. Other than this, and the irregular distribution of quartz phenocrysts, the unit is homogeneous; country rock xenoliths were not observed. Unequivocal crosscutting intrusive contacts with supracrustal rocks to the north are exposed at a number of localities, particularly near Highway 102 where unit Gq displaces much of the supracrustal succession. Thin quartz-eye granite sills and dykes are common throughout units M and F in this area, but are rare or absent in the adjacent supracrustal units. The northwest-striking contact between unit M and the main body of unit Gq is sheeted and may be slightly sheared. Quartz-eye granite was not observed to intrude the felsic schists (unit R) to the south.

Rare quartz-eye granite sills exposed in the Five Fingers and MacKay Lakes area intrude mafic to intermediate volcanic rocks. Contacts are sharp and conformable, with sills as thin as 0.5 m being observed. At two localities on Five Fingers Lake,

these sills occur adjacent to thin ultramafic bodies and were likely intruded along the same zone of weakness utilized by the ultramafic rock. In this same area, quartz eyes locally attain diameters of up to 10 mm and display extremely irregular embayed shapes.

In the extreme south, a felsic feldspar porphyry (unit Gf) pluton and surrounding dyke/sill swarm are exposed. The porphyry is a homogeneous fine- to rarely medium-grained granitic rock with 5 to 10 percent biotite and 15 to 25 percent round pink feldspar phenocrysts 0.5 to 2 mm in size. Quartz-phyric textures occur locally, as do aphanitic nonporphyritic felsites. Small mafic and biotite-garnet schist enclaves were observed, but are rare. Unit Gf dykes and sills from 0.4 to 2 m thick constitute a considerable part of the exposed bedrock for more than 1 km north of the margins of the porphyry pluton, and extensively intrude felsic schists (unit R) and quartz-eye granite (unit Gq), as well as mafic schists (unit M) along the highway. Similar feldspar porphyry sills occur sporadically throughout the MacKay Lake South area, but are not necessarily related to this pluton.

At MacKay Lake, an extensive composite intrusion, mainly comprising hornblende diorite-gabbro (unit D) and hornblende-biotite granodiorite (unit Gd) forms the northwest arm of the larger Little Deer Pluton exposed to the southeast (Lewry and Slimmon, 1985; Slimmon, this volume; Sibbald, this volume). Intermediate to basic rocks of unit D vary greatly in texture and composition, but are generally medium to coarse grained and hornblende bearing with or without biotite and quartz. The mafic content ranges from 25 to 60 percent of the rock. Multiple intrusive phases are evident, comprising fine-grained melagabbro intruded by coarser leucogabbro, diorite and quartz diorite. Isolated occurrences of ultramafic rock (unit U) could conceivably be part of this plutonic spectrum. Alternatively, they could either be later sills, as has been suggested for the other ultramafic occurrences in the map area, or xenoliths. Enclaves are generally rare within unit D. Grain size variations from fine to coarse, and textural variations from equigranular to porphyritic are common in these plutonic rocks, in places occurring over outcrop-scale distances. Both subhedral feldspar phenocrysts and glomeroporphyritic hornblende are present. The intrusive rocks are generally massive. Where foliated or lineated, the structures seem to be nonpenetrative and can be related to common west-northwesterly-trending shears which vary in form from discrete foliated bands less than 1 cm wide to 10 m wide fluxion zones containing laminated and mylonitized diorite-gabbro. Shear-related effects include quartz-epidote veins and stockworks, chloritized/biotitized mafic minerals, felsic aplite and pegmatite apophyses, reddened feldspars and thin crush zones. The main locus of shearing appears to run along the south shore of MacKay Lake in a west-northwesterly direction, coincident with pluton contacts. Tightly folded mylonitic fabrics observed at one locality suggest protracted deformation along this cataclastic zone.

Unit D is also exposed in a small body within felsic feldspar porphyry (unit Gf) to the south. These rocks are also massive and contain hornblende and/or biotite and/or quartz. Prograde epidote is an abundant constituent. Direct evidence regarding age relationships between this body and the surrounding porphyry is lacking.

Hornblende-biotite granodiorite (unit Gd) mainly occurs along the southwest margin of the segment of Little Deer Pluton exposed within the map area. It intrudes the unit D diorites and gabbros to the north. The rock is generally a grey medium-grained equigranular to porphyritic granitoid with less than 20 percent mafics, in which biotite is subordinate to hornblende. Like unit D, rapid textural and grain size variations are common, but, unlike unit D, the granodiorites are usually penetratively foliated, and discrete to partially assimilated country rock enclaves are abundant. These enclaves range from a few centimetres to tens of metres in size and are usually oriented with their long dimension parallel to foliation. In a few cases, enclaves display internal structures such as banding/foliation and rodding oblique to structure in the granodiorite, implying metamorphism and deformation of the enclave prior to inclusion in the granodioritic magma. The granodiorite contact with mafic to intermediate schists (unit M) to the south is diffuse and gradational for 50 m or more, where exposed rocks are neither clearly supracrustal nor intrusive. Dykes and sills of granodiorite within the supracrustal rocks are not present. This intrusive mechanism of passive assimilation contrasts sharply with that exhibited by the more or less enclave-free sharply bounded dyke/sill-forming felsic porphyritic bodies exposed in the south part of the map area (units Gq and Gf). The shearing which characterizes unit D diorite-gabbro is only evident in the granodiorites north of the southwest arm of MacKay Lake, where a red biotitic flasered felsic gneiss is exposed.

Biotite granite (unit G) occurs sporadically throughout the map area. These rocks vary from place to place but are generally pink to white, leucocratic, fine to medium grained and equigranular with about 5 percent biotite. Granitic rocks in the Little Deer Pluton are foliated and contain abundant xenolithic material similar to associated granodiorites (unit Gd). The granite body intruding unit GK 'metagreywackes' near the highway is commonly banded to foliated near its edges but is otherwise generally massive. Semipelitic enclaves are locally present; granitic dykes and sills intrusive into the 'metagreywackes' are not. This body thus shares some characteristics with the Little Deer Pluton exposed less than 1000 m to the east (Forsythe, 1968).

Isolated outcrops and felsenmeer of biotite granite (unit G) as well as hornblende-biotite granodiorite (unit Gd) occur on the east side of MacKay Lake within a more or less well-defined aeromagnetic low (Geological Survey of Canada, 1953). Geological contacts outlining the outcrops and the magnetic low have been depicted on the geological map, inferring the presence of a discrete felsic pluton in this region.

## Structural Geology

Three penetrative deformational episodes are recognized in the MacKay Lake South area. Schistosity parallel to banding and supracrustal lithological contacts is the earliest identifiable tectonic fabric ($S_1$). Neither minor nor major folds related to this $D_1$ event are apparent.

Mesoscopic effects of a second deformational episode are in evidence exclusively within unit GK 'metagreywackes', where the strongly banded and biotitic nature of the rocks favours the development and preservation of overprinting fabrics. These rocks commonly display a second northwesterly-striking and steep northeasterly-dipping foliation ($S_2$) which crosscuts banding and the parallel $S_1$ foliation ($S_0$-$S_1$) at an acute angle. The $S_2$ foliation takes the form of aligned biotite flecks in psammopelitic bands, and fracture cleavage in psammitic bands; cleavage refraction from one band to the next is common. The $S_2$ foliation is axial planar to tight and generally asymmetrical minor folds in the banding. Minor fold axes and rodding structures plunge moderately to the southeast. The mapped distribution of both $S_2/S_0$-$S_1$ intersection asymmetry and minor fold asymmetry indicates the presence in this area of a major tight $D_2$ antiform cored by 'metagreywacke' (Fig. 1). With one exception, way-up evidence derived mainly from graded psammitic interbeds in unit GK corroborates the presence of the $D_2$ major structure; these rocks young away from the $D_2$ axial trace towards the flanking mafic to intermediate schists. The structure in this area is therefore an antiformal anticline.

The third deformational event is most readily identified in the south where northwest-striking rock units and parallel $S_0$-$S_1$ fabrics are openly folded about a north-northeast-trending moderate to steeply plunging axis. The axial trace of this synformal structure runs just west of and subparallel to Highway 102. Well-developed rodding, as well as north-northeast-striking and steeply dipping $S_3$ planar fabrics, which include schistosity, fracture cleavage and cataclastic foliation, are particularly well developed in the $D_3$ hinge zone. Microlithons of banded rock preserved between $S_3$ foliation planes indicate incipient transposition of earlier planar fabrics into the $S_3$ orientation. Minor shearing has probably taken place along this hinge zone. Mesoscopic folds related to the $D_3$ event are few and mainly occur in the compositionally well-banded mixed metasediments (unit X). Along the $D_3$ hinge zone toward the north, unit GK 'metagreywackes' have generally resisted transposition and instead exhibit a crosscutting $S_3$ foliation or fracture cleavage. In this region, any $S_2$ foliation which may have been present has been obliterated. Subvertical lineations in unit GK reflect a progressively steepening plunge from south to north of the $D_3$ major fold. North of the 'metagreywackes' towards MacKay Lake, the $D_3$ structure loses its definition and $S_3$ fabrics are absent. Subvertical lineations probably related to the $D_3$ event occur at least as far north as Five Fingers Lake.

Structural elements present in the Little Deer Pluton and rocks to the north of it are not easily related to the three deformations evident to the south because overprinting relationships are not discernible. Layer-parallel foliation in the schists of units R and M is probably of $D_1$ age. Cataclastic structures related to the west-northwest-striking shears along the south shore of MacKay Lake crosscut and postdate this foliation. The age of shearing relative to the $D_2$ and $D_3$ deformations is open to speculation.

Postorogenic structures observed in the map area are restricted to numerous topographic linears evident on air photographs, which presumably mark bedrock fractures. No movement or deformational effects related to these linears was detected.

## Metamorphism

All rocks within the map area have been regionally metamorphosed. The presence of prograde minerals such as garnet, anthophyllite, staurolite, hornblende, diopside, epidote, biotite and muscovite indicates metamorphic conditions in the upper greenshist/lower amphibolite range. Some minerals, such as garnet and hornblende, commonly occur both as xenoblastic pretectonic and idioblastic posttectonic porphyroblasts, implying distinct metamorphic pulses reaching roughly the same maxima. At one locality in the south, idioblastic hornblende occurring in a quartz vein parallel to $S_3$ foliation implies at least upper greenschist conditions during $D_3$ tectonism. Metamorphic grade during at least some of the cataclastic deformation at MacKay Lake must also have been quite high, since hornblende in mylonitized diorite-gabbro (unit D) has not been retrogressed; at other localities, however, chloritized sheared rocks are evident. The common occurrence throughout the map area of small muscovite flakes oblique to foliation is probably a posttectonic retrograde effect.

Contact metamoprhism is not obvious adjacent to the various plutons in the area, but as the plutons have been regionally metamorphosed, any contact effects that may have been present are probably masked. Nevertheless, the occurrence of

unoriented idioblastic staurolite on the west end of MacKay Lake within 300 m of the Little Deer Pluton could be attributed to contact metamorphism. In the same area, the common occurrence of massive dense nondescript fine-grained rocks may represent hornfels.

## Economic Geology

No important economic mineral deposits have been located in the MacKay Lake South area to date, but a number of sulphide showings have been reported.

Forsythe (1971) described three pyrite-pyrrhotite-graphite gossans from the west side of Highway 102 in the south part of the area, the two most southerly of which occur in sheared rodded rocks at the contact between units Gf or R, and unit M (see accompanying geological map). This shearing parallels the $D_3$ synformal fold hinge in the area and is probably $D_3$ in age. Additional gossans or shearing were not encountered during mapping inland from the highway, and the shearing and associated sulphide occurrences are likely restricted to the $D_3$ hinge zone. The proximity to mafic metavolcanic rocks (unit M) may also be important. The northernmost of these two occurrences is reported to display quartz veining with arsenopyrite and possibly has some gold potential (Forsythe, 1971).

The third, northernmost showing reported by Forsythe also occurs in the $D_3$ fold hinge area, probably within unit X mixed metasediments, which are commonly rusty and pyritic. Shearing is not as evident in this area as to the south and the occurrence may be genetically related to the pelites and chemical sediments comprising unit X. It is noteworthy that 600 m west of the highway and immediately adjacent to this same horizon of unit X, a chalcopyrite-bearing quartz vein occurring in altered mafic rock (hornblende-epidote-calcite) returned an assay of over 1 oz./ton Au (D. Studer, pers. comm.). The quartz vein is north-northeast-striking and steeply dipping and thus is parallel to $S_3$ fabrics in the region.

Drill-intersected disseminated and massive pyrite-pyrrhotite-graphite in unit Bn biotite wackes (Assessment File 73P07-0103) may be a similar type of occurrence as found in unit X. Extensive sulphide-bearing zones were not observed during the mapping, but it is conceivable that sulphide-facies iron formation occurs within these rocks. Metal assays from the drill core were not encouraging and gold was not detected. Recently, however, surface samples from this region have reportedly returned anomalous gold values (A.J. Gracie, pers. comm.).

Although occurrences reported to date may be few, the MacKay Lake South area does exhibit other geologically favourable environments for mineralization:

1) The Little Deer Pluton, being a composite sheared intrusive, bears similarities to other Plutons in the La Ronge Domain presently being evaluated for their gold potential (Coombe, 1984). In this regard, sheared biotitized and quartz-veined diorite-gabbro (unit D) occurring in the extreme west is similar to rocks hosting gold at the PAP showings southwest of Preview Lake (Forsythe, 1971; Coombe, 1984; Sibbald, pers. comm.).

2) There is potential for skarn-type mineralization in intravolcanic calc-silicate rocks (unit C) exposed in the Five Fingers Lake area; mineralized skarns are reported from Teneycke Lake a few kilometres to the east (Coombe, 1984).

3) A biogeochemical gold anomaly from 3 to 30 times background straddles Highway 102 just northeast of the small granite pluton intruding unit GK 'metagreywackes' (Dunn, 1984). This anomaly is near felsic to basic intrusive rocks to the east (Slimmon, this volume; Sibbald, this volume) and the granitic pluton to the southwest, and is also bisected by the $D_3$ hinge zone which parallels the highway in the south part of the map area. Any or all of these features could conceivably be contributing to the localization of gold mineralization. Barren sulphides have been reported from the southeast end of the biogeochemical anomaly (Forsythe, 1971). Alternatively, the anomaly could be caused by Pleistocene glacial deposits which are plentiful in this particular area.

## Summary and Inferences

The following salient features arise from mapping of the MacKay Lake South area:

1) The area transects a major second generation northwesterly-trending tight to isoclinal antiform cored by 'metagreywacke' of the Crew Lake Belt. A rough symmetry from 'metagreywacke' to intercalated volcanic/volcaniclastic rocks to felsic schists (tuffs) occurs on both sides of the $D_2$ axial trace. The predominantly mafic to intermediate supracrustal package at Five Fingers Lake is laterally equivalent to the more varied felsic to mafic volcanogenic rocks occurring immediately south of the 'metagreywackes'. Rapid lateral facies variations, which are evident in the rocks comprising each area, serve to explain the drastic lithological differences between the two belts.

2) The $D_2$ antiform has been subsequently folded by a north-northeast-trending $D_3$ structure to generate a Type 3 fold interference pattern (Ramsay, 1967). This interference pattern is not evident on existing maps (Forsythe, 1968) because the Little Deer Pluton has intruded,

displaced and assimilated most rocks east of Highway 102 where the $D_2$ closure would crop out. The same folds are probably evident, however, northeast of the Little Deer pluton (Forsythe, 1968; Lewry, this volume; Slimmon, this volume). The fold hinge passing through Heyer Bay and Mullock Lake is likely the northeasterly extension of the $D_3$ structure. The major closure at Ramsland Lake represents the $D_2$ fold nose.

3) The Little Deer Pluton is most probably a syn- to late-$D_3$ intrusive, based simply on the observation that the pluton is unlikely to have undergone the postulated $D_2$ tight to isoclinal and subsequent $D_3$ folding episodes, and remain unfoliated. The same reasoning applies to the small granite body intruding unit GK 'metagreywacke'. A late tectonic age for the Little Deer Pluton is also implied by the presence of previously tectonized enclaves within the intrusive mass. A late intrusive age would indicate that the shearing so prevalent in unit D diorite-gabbro is post-$D_3$. The foliation present in unit Gd granodiorite on the south edge of the Little Deer Pluton may have been acquired during this shearing, or alternatively is an inherited fabric paralleling country rocks in the area.

4) In the extreme northwest part of the area, the contact between unit GK 'metagreywacke' and the Little Deer Pluton is strongly sheared. The abrupt change in strike in the 'metagreywackes' in this region from northerly to west-northwesterly suggests that much of the 'metagreywacke' section has been truncated here, as have the Five Fingers Lake volcanogenic rocks. This truncation could be simply due to a crosscutting intrusive contact. It is conceivable, however, that the truncation is fault related and the Little Deer Pluton in this area has been intruded along a pre-existing displacement zone. The relationship of a possible early, northwesterly-striking truncation zone in this area to the McLennan Lake Thrust, which strikes into Heyer Bay, MacKay Lake from the north (Lewry and Slimmon, 1985; Lewry, this volume), is open to speculation.

5) Quartz-eye granite (unit Gq) is the oldest intrusive rock in the area, exhibiting an $S_1$ foliation and sheeting structure which, near $D_3$ fold noses, is transposed into a northeasterly-trending $S_3$ foliation. The intrusive probably predates all three postulated deformational episodes.

6) Felsic feldspar porphyry (unit Gf) intrudes quartz-eye granite and displays only northeasterly-trending $S_3$ foliations. The presence of only $D_3$ fabrics in this unit is attributed to the overprinting effects of a $D_3$ antiform (evident from airphotos and structural orientation data) situated about 600 m west of the map area, as well as to the $D_3$ synform along Highway 102. Earlier fabrics which may have been present in this region have been obliterated. The feldspar porphyry is known to postdate the quartz-eye granite and is considered to predate tectonism, a conclusion inferred from the intrusive mechanism shared by both rock types.

7) The massive unit D diorite-gabbro body occurring in unit Gf feldspar porphyry is probably a satellite intrusive related to the Little Deer Pluton, which outcrops a few kilometres to the northeast.

8) The contact between 'metagreywackes' of the Crew Lake Belt and the metavolcanic-volcaniclastic rocks is considered to be a stratigraphic continuum; with the exception of the northwest part of the area discussed above, no intrusion or major structural displacements have taken place along this contact in the MacKay Lake South area. Available way-up indications, with one exception, suggest that the metavolcanics overlie the 'metagreywackes'. This conclusion is at variance with areas to the north where rocks of the Crew Lake Belt are considered to overlie the metavolcanic rocks (e.g., Thomas, 1984, 1985). It is possible that shearing and intrusion which typify this contact in the northern part of the La Ronge Domain have obscured the stratigraphic relationships. Alternatively, the top indicators from the MacKay Lake South are untrustworthy (Bishop and Force, 1969). That's geology for you.

9) Most volcanogenic rocks exposed in the map area are considered to be pyroclastic tuffaceous rocks or reworked derivatives. Flow rocks are rare and are probably mainly represented by homogeneous hornblende-blastic mafic and intermediate schists.

10) The structural/stratigraphic interpretation presented in this report indicates that the complex package of supracrustal rocks at Sulphide Lake noted for its gold mineralization does not correlate laterally with supracrustal rocks exposed in the MacKay Lake South area, but rather stratigraphically overlies them.

Acknowledgments

The author gratefully acknowledges the field assistance of D. Dyck and M. Liskowich, as well as the irrepressible hospitality of A.J. Gracie, resident geologist in La Ronge. Discussions with C.T. Harper, J.F. Lewry, T.I.I. Sibbald, W.L. Slimmon and D.J. Thomas concerning various aspects of the geology of the La Ronge Domain are much appreciated.

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Project 8606A

# Bedrock Geological Mapping, Sulphide Lake Area (Part of NTS 73P-7)

by T.I.I. Sibbald

Sibbald, T.I.I. (1986): Bedrock geological mapping, Sulphide Lake area (part of NTS 73P-7); in Summary of Investigations 1986, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 86-4.

An area surrounding Sulphide and Pap Lakes, bounded by Highway 102 in the west and the Stanley Mission road in the southeast, was geologically mapped at a scale of 1:20,000. Adjacent regions to the north and the west are reported in this volume by M.W. Thomas and W.L. Slimmon respectively. Previous geological studies by the Saskatchewan Geological Survey include work by Forsythe (1968, 1971), Coombe (1976) and Sibbald (1984). The various gold occurrences are described by Coombe (1984).

The area comprises metavolcanic and metasedimentary rocks intruded by the composite and possibly syntectonic gabbroic-granodioritic Contact Lake Pluton, as well as by numerous smaller bodies of gabbroic to granitic composition. A sill-like mass of K-feldspar porphyritic granite trends northeasterly through Aikenhead, Jepson and Freda Lakes along the southeastern and eastern edge of the area. This granite is zoned marginally to strongly foliated biotite-hornblende-epidote granodiorite gneiss. At least two episodes of deformation influenced the supracrustal rocks which are metamorphosed to upper greenschist to lower amphibolite facies.

Table 1 - Generalized stratigraphic succession (from southeast to northwest)

| | |
|---|---|
| 6. | Calcareous metasediments, mixed oxide-silicate-sulphide iron formation |
| 5. | Monotonous well-laminated psammopelitic metasediments (upper greywackes) |
| 4. | Felsic to intermediate metavolcaniclastics, minor pillowed flows (meta-andesite?), interlayered pelitic metasediments in part carbonaceous and sulphidic (lean iron formation). |
| 3. | Mafic pillowed flows, intercalated mafic sills (interdigitates with Unit 2 and thins to northeast) |
| 2. | Intermediate to felsic flows and metavolcaniclastics, calcareous metasediments, mixed silicate-sulphide iron formation. |
| 1. | Psammopelitic metasediments, in part calcareous (lower greywackes (see Thomas, this volume)) |

The supracrustal succession (Table 1) is thought to young consistently to the southeast, on the basis of way-up indications from graded bedding and pillow shapes, and is therefore overturned.

Most known gold occurrences are hosted in the felsic to intermediate metavolcaniclastics (Unit 2) described in more detail below, and in the gabbro-diorite bodies that intrude them. Southwest of Sulphide Lake, this unit comprises predominantly monotonous grey to green, fine-grained, finely foliated and generally poorly layered metavolcaniclastics. Coarse clastics are rare, although feldspar-phyric rocks with feldspar crystals up to 7.5 mm in size are common. In great part these latter are thought to be dacitic crystal tuffs, although, feldspar porphyry intrusives are definitely also present. Mafic content, which forms one basis for subdivision of the metavolcaniclastics, commonly ranges between 10 and 30 percent. Felsic (rhyolitic) and mafic (basaltic) end members are subordinate. Sporadically interlayered fine-grained pelitic metasediments are in part black, carbonaceous and sulphidic. Pillowed volcanics, of probable andesitic composition, outcrop north of the Studer A and B Zones. To the north of Sulphide Lake (Pap Lake area), Unit 2 contains more felsic (rhyolitic) rocks and less feldspar-phyric rocks, and several bodies of gabbro-diorite.

The area has undergone at least two folding deformations. The first of these is marked by rare minor isoclinal folds. Major structures were not identified, although in the area to the west, Thomas (this volume) has recognized a major anticline whose axial trace becomes incorporated within the Contact Lake Pluton in the presently described area. There is some uncertainty as to whether these earliest recognizable folds postdate or are synchronous with development of the regional schistosity. The second fold event caused major open folding and widespread minor folding. Minor folds are close to open and plunge steeply to the north, and axial surfaces commonly dip steeply west to west-northwest. Thomas (this volume) reports a major fold closure of this age immediately west of Highway 102.

Several types of gold mineralization are recognized. The Studer, Galena, Caribou and Gem gold zones appear closely related to the black carbonaceous, sulphidic pelitic metasediments or

lean iron formation (Coombe, 1984) of Unit 2. Gold is accompanied by arsenopyrite, pyrite, galena and chalcopyrite in quartz veins and gashes, and in association with sulphide disseminations in bedrock. The mineralization is not unique to the carbonaceous metapelites but appears also in the bounding metavolcaniclastics. Mapping and geophysics suggest that the Studer A, B and F, Galena and Caribou zones lie in the same stratigraphic unit (see also Forsythe, 1971; Coombe 1984). The Studer D and E and Gem zones, although similar, may occur at one or more other stratigraphic levels. As noted by Sibbald (1984), the carbonaceous metapelites clearly reflect a low rate of sedimentation related to hiatuses in volcanism and thus provide a suitable environment for seafloor concentration of metals.

In the Pap Lake area, mineralization is found predominantly in shear zones in gabbro-diorite bodies (Pap A, B and SW zones). Gold occurs together with arsenopyrite, pyrite and rare galena in quartz veins. The shear zones are up to a few metres wide and within them the undeformed gabbro-diorite becomes progressively foliated and transformed to biotite schist, indicating the role of K-metasomatism in the mineralization process. Similar relationships are seen at the Seabee property on Laonil Lake (Delaney, this volume). Occurrences of lean iron formation type are also present in the Pap Lake area (Clearwater A and B zones).

A third type of mineralization is marked by dilational gold-quartz veins in coarse feldspar-phyric rocks of dacitic composition (Lucky Strike and Discovery zones) and their finer grained equivalents (Studer C zone).

The area offers several possibilities for further discoveries of mineralization.

1) lean iron formation in Unit 2, in the largely drift-covered region between Lynx Lake and Contact Lake, and in Unit 4 east and northeast of Sulphide Lake;

2) shear zones in the Contact Lake Pluton; and

3) mixed oxide-silicate-sulphide facies iron formations in the calcareous metasediments of Unit 6.

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Project 8624B

# Nistowiak Lake Tectonic Studies (Part of NTS 73P-7)

by J.R. Chiarenzelli[1] and V.K. Chiarenzelli

Chiarenzelli, J.R. and Chiarenzelli, V.K. (1986): Nistowiak Lake geology project (part of NTS 73P-7); in Summary of Investigations 1986, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 86-4.

Geological mapping of bedrock exposures in the Nistowiak Lake area was begun in June 1986. Approximately 100 km$^2$ were mapped at 1:20,000 (Fig. 1 and accompanying map). The area investigated includes Nistowiak and Drope Lakes, both part of the Churchill River system. The centre of the field area is about 75 km northeast of La Ronge and 10 km downriver from Stanley Mission.

Previous geological mapping in the area includes the Stanley area, NTS 73P-7E and -8W (Mawdsley and Grout, 1951) and the Nistowiak Lake area (east half), NTS 73P-8E (Morris, 1962). Reconnaissance geological investigation of the area was carried out during the 1984 field season by J.F. Lewry in preparation for the Lac la Ronge (NTS 73P/7I) 1:250,000 scale bedrock compilation map (Lewry, 1984; Lewry and Slimmon, 1985).

The major goals of this study are to utilize field, petrographic, geochemical and geochronological data from the Nistowiak Lake area to 1) provide a geochronological framework constraining the timing of deformational, metamorphic, anatectic and tectonic events affecting rocks in the study area; 2) determine the spatial distribution and regional significance of the Guncoat and Nistowiak Gneisses, and the processes responsible for their deformation; and 3) develop and test models for the tectonic history of the region with emphasis on the origin of the Glennie Lake Domain and its accretion to the La Longe arc.

## Regional Geology

The Nistowiak Lake area is underlain by Precambrian rocks of the Glennie Lake Domain (Lewry, 1981), Trans-Hudson Orogen. The eastern and western boundaries of the domain are the regionally significant Stanley Shear Zone and Tabbernor Shear Zone respectively. The Glennie Lake Domain has been separated into the Wapassini Allochthon and the Iswatikan Subdomain (Lewry, 1984).

The Wapassini Allochthon, to the north, is composed of mixed supracrustal rocks similar to those of the adjacent MacLean Lake Belt where the allochthon is suspected to root. The MacLean Lake rocks have been interpreted as the telescoped remnants of a fore-arc basin which was thrust on to the Glennie Lake Domain during collision with the La Ronge arc (Lewry, 1981).

The Iskwatikan Subdomain structurally underlies the Wapassini Allochthon and consists of a wide variety of variably strained plutonic rocks, ranging in composition from quartz diorite to granite, and minor supracrustals. The Nistowiak Gneisses, which are grouped as part of the Iskwatikan Subdomain, consist of strongly deformed to mylonitic gneisses derived almost exclusively from plutonic (commonly migmatitic) protoliths (Lewry, 1984). Although the Nistowiak Gneisses are thought to delineate a major shear zone with considerable displacement, unsolved structural problems make their regional significance less clear.

The Wapassini Allochthon and the Iskwatikan Subdomain are separated by the Guncoat Gneisses, a zone of migmatized and highly strained pelitic and psammitic rocks thought to represent the sole of the Wapassini Allochthon (the Guncoat Thrust of Lewry and Slimmon, 1985).

U-Pb zircon geochronology (Van Schmus et al., in press) from rocks of the Glennie Lake Domain suggests it is composed of juvenile crust essentially coeval with volcanic and plutonic rocks in the La Ronge Domain (ca. 1.89 to 1.85 Ga).

## Ultramafic Rocks (Unit 1)

Ultramafic rocks occur abundantly, as tectonic blocks up to 250 m in size, within psammitic gneisses on the islands in Drope Lake. These rocks are massive and dark green. Weathering surfaces locally contain round knobs 1 to 2 cm in diameter that are similar in appearance to oikocrysts. Discordant serpentine veins 1 to 2 cm thick were noted in one outcrop. Most of the primary minerals are replaced by diopside, serpentine, talc and/or tremolite. A bright orange lichen is typically associated. Chemical data from two outcrops (J85-162 and J85-183) are given in Table 1. Rounded pods and discontinuous layers of coarse-grained black and green hornblendite, produced by anatectic or metamorphic segregation,

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Field expenses for the project funded under the Saskatchewan component of the Canada-Saskatchewan Subsidiary Agreement on Mineral Development 1984-89.

**Table 1 - Major and Trace Element Geochemistry of Selected Samples from the Nistowiak Lake Area**

| | J85-37 | J85-177B | J85-177C | J85-177D | J85-162 | J85-183 |
|---|---|---|---|---|---|---|
| $Na_2O$ | 5.15 | 3.25 | 2.38 | 1.94 | 1.11 | 0.72 |
| MgO | 0.26 | 4.31 | 4.40 | 12.87 | 21.84 | 24.81 |
| $Al_2O_3$ | 16.20 | 16.56 | 16.56 | 12.42 | 4.55 | 6.73 |
| $SiO_2$ | 74.31 | 60.83 | 61.11 | 45.67 | 49.73 | 44.09 |
| $K_2O$ | 3.50 | 2.08 | 2.03 | 1.59 | 0.16 | 0.35 |
| CaO | 1.66 | 5.15 | 6.17 | 12.32 | 11.16 | 12.96 |
| $TiO_2$ | 0.03 | 0.80 | 0.88 | 1.18 | 0.21 | 0.85 |
| $Fe_2O_3$ | 0.81 | 7.52 | 6.35 | 11.10 | 11.16 | 12.96 |
| LOI | 1.75 | 1.41 | 1.04 | 2.79 | 4.25 | 6.16 |
| TOTAL | 101.40 | 100.50 | 99.88 | 99.09 | 99.93 | 97.89 |
| Trace Elements (ppm): | | | | | | |
| Zr | 73 | 120 | 117 | 161 | 29 | 44 |
| Rb | 37 | 44 | 45 | 43 | 4 | 9 |
| Y | 2 | 12 | 7 | 29 | 4 | 7 |
| Nb | 8 | 11 | 11 | 7 | 5 | 6 |
| Th | 2 | 4 | 4 | 9 | 2 | 2 |
| Pb | 11 | 4 | 3 | 0 | 0 | 3 |
| Sr | 764 | 538 | 500 | 740 | 96 | 203 |
| Ba | 998 | 404 | 661 | 462 | 66 | 38 |

* Analytical work was done on a Riguka X-ray fluorescence unit at the Department of Geology, University of Kansas.

are also found in highly deformed orthogneisses in the area (Lewry, 1977). In one outcrop, coarse-grained green hornblendite layers of this type occur in a medium-grained amphibolite.

## Supracrustal Rocks (Units 2 to 5)

A wide variety of supracrustal rocks constitute almost 25 percent of the area, mostly occurring in a north-northeast-trending belt, 2 to 3 km wide, between Drope and Nistowiak Lakes. Within the Nistowiak Gneisses, supracrustal rocks occur mainly as thin semicontinuous rafts or screens. In several areas, such as around Stanley Rapids, the granodioritic gneisses are seen to include the supracrustals. Stratigraphic relationships are obscured by deformational and intrusive events. Supracrustal rocks also occur as xenoliths in the granodioritic gneisses discussed below.

### Hornblende-Plagioclase-Diopside Gneisses (Unit 2)

A wide variety of rocks which could be termed hornblende-plagioclase granulites on textural grounds are exposed in an anastomosing belt between Drope and Nistowiak Lakes. Most of these rocks are medium grained, granular, layered, dense and generally monotonous, and are composed of subequal amounts of hornblende and plagioclase with or without varying amounts of diopside. Layering is generally defined by centimetre-scale mineralogic banding which is laterally persistent through outcrops. Layering related to grain-size variation is less important, but in places accompanies mineral variation. Coarse-grained segregations rich in plagioclase and diopside occur locally. In several of these segregations orthopyroxene was tentatively identified.

Much of this unit is thought to be of mafic volcanic or volcanogenic origin. Several relatively thin units with a strong folded linear fabric contain granulated elongate plagioclase domains up to 2 cm in length. This unit may be interpreted as derived from phenocrystic metalavas or metatuffs.

### Psammitic Gneisses (Unit 3)

A relatively thick sequence of psammitic gneiss outcrops on islands along the western shore of Drope Lake and around Thorpe Bay in Nistowiak Lake. These rocks are composed of quartz, plagioclase, biotite, as well as minor muscovite, garnet and plagioclase porphyroclasts up to 10 mm in diameter. Variation in biotite content defines centimetre-scale layers. In many areas discontinuous layers and pods of coarse-grained tonalitic neosomal material are present. Psammitic and pelitic varieties are interlayered locally. Psammitic gneiss exposed in Thorpe Bay grades along strike into pelitic gneiss, in a relationship suggestive of sedimentary facies change. Psammitic gneisses in the Drope Lake area differ from those in the Nistowiak Lake area in containing discontinuous ultramafic layers and pods.

### Pelitic Gneisses (Unit 4)

Pelitic gneisses consisting of plagioclase, quartz, biotite, garnet and minor sillimanite occur throughout the map area as thin screens and rafts. A thicker and more continuous band of pelitic gneisses is found along the western shore of Nistowiak Lake and extends northward where its outcrop pattern is complicated by fold interference patterns. Highly migmatized pelitic gneisses are also interlayered with tonalitic leucosome. In areas of high strain, dismemberment of the leucosome has produced numerous plagioclase porphyroclasts and presumed rolling of garnets. Distinctive 1 to 2 m thick garnet-hornblende layers are included with the pelitic gneisses.

### Marble, Impure Marble and Calc-Silicate Rock (Unit 5)

Several thin discontinuous sheets of marble (subunit 5m) less than 10 m thick are generally associated with the pelitic gneisses, although no consistent stratigraphic relationships are apparent. The marble is probably attenuated and dismembered from larger bodies, such as that mapped north of Nistowiak Lake (Mawdsley and Grout, 1951). The marble is white to grey to pale blue, coarse grained and fairly massive. Only the white marble is relatively pure; other varieties contain sphene and diopside.

Carbonate-bearing calc-silicate rocks (subunit 5cs) are more abundant than marble, and in some areas can be traced for several kilometres along strike. One unit can be traced on islands along the eastern shore of Drope Lake and in discontinuous outcrop north-northeastward for a distance of at least 5 km. This unit consists of alternating carbonate and silicate layers (plagioclase, quartz, diopside, sphene) which are tightly folded. In several areas the calc-silicates form the base or top of a relatively thick sequence of hornblende-plagioclase gneisses. Whether this is merely coincidental or stratigraphically significant remains to be demonstrated.

## Plutonic Rocks (Units 6 to 10)

A wide variety of plutonic rocks makes up approximately 70 percent of the mapped area. In this report, these rocks are classified by their age relationships relative to deformation and metamorphism wherever possible.

### Migmatites (Unit 6)

As Mawdsley and Grout (1951) and Morris (1962) pointed out, migmatitic rocks are common in the area. Many of the rocks mapped as migmatite in previous studies may be regarded as products of metamorphic segregation and are not mapped as migmatite per se. We have attempted to correlate units on the basis of protolithology rather than subsequent deformational or metamorphic overprint.

Unit 6 is a distinctive migmatite consisting of irregular elongate domains and layers of dioritic to gabbroic material surrounded by severely strained anastomosing granitic sheets, some of which are mylonitic and folded. Exposed relationships suggest melt-enhanced deformation (Hollister and Crawford, 1986) and possibly a synchroneity or causal relationship between anatexis and shearing in the area. An entire sequence ranging from relatively less deformed agmatitic migmatite to a heterogeneous well-layered gneissic tectonite is exposed along the north and west shores of Hall Island.

### Frog Narrows Complex (Unit 7)

A suite of strongly deformed northeasterly-trending plutonic rocks intrudes the supracrustal sequence. Rock types include gabbro, quartz diorite, hornblende granodiorite and biotite granodiorite.

Medium grey hornblende granodiorites (subunit 7gd) are dominant and exhibit strong gneissic foliation, a distinct variation in mineral composition and grain size related to metamorphic segregation, and numerous fine-grained leucogranodioritic layers, all of which are concordant with the regional foliation. Also common in these rocks are sparse to abundant potassium feldspar megacrysts and hornblende porphryoblasts. Numerous "beaded" plagioclase grains suggest strong deformation (Lewry, 1984). Xenoliths of ultramafic, amphibolitic, calc-silicate and layered metavolcanic(?) rocks are present and are particularly abundant in some marginal zones of the plutons.

Gabbroic and quartz dioritic rocks (subunit 7gd) are generally composed of hornblende, plagioclase and minor quartz. Some gabbros have remnant pyroxene. With increasing deformation these rocks develop into mafic augen gneisses. A large belt of gabbroic rocks is shown on strike with granodioritic and quartz dioritic rocks just northeast of Purmal Bay, in a transition which marks either a plutonic contact or is gradational due to strong deformation. Some of the gabbro exposed around Coghill Lake is rhythmically layered, and in one exposure an angular relationship between the layering and gneissic foliation was observed.

Biotite granodiorite and granite (subunit 7gr), which occurs locally, is generally less deformed and foliated, and may have been intruded slightly later in the deformation sequence.

### Nistowiak Lake Complex (Unit 8)

This complex is exposed on the islands in the center of Nistowiak Lake where it probably represents the least deformed core of the Nistowiak Gneiss Allochthon. A restricted compositional range includes garnetiferous amphibolite to quartz diorite to mafic tonalite. Commonly the rocks contain thick discontinuous quartzofeldspathic layers 1 to 3 m thick which are intensely laminated, chaotically folded and migmatitic. In most areas these quartz dioritic to tonalitic plutonic rocks are foliated but devoid of metamorphic segregation or migmatization. An exception is a fairly distinctive "tiger gneiss", comprising numerous pink bifurcating coarse-grained granitic sheets of probable anatectic derivation and abundant garnet. Distinctive mafic augen gneisses occurring in thin layers or sheets throughout the area may be deformed porphyritic equivalents of these rocks or deformed phenocrystic metavolcanics.

### Late Plutonic Rocks (Unit 9)

Late granitic rocks with a weak penetrative foliation occur on the eastern margin of the area and increase in abundance to the east (Morris, 1962).

### Pegmatite (Unit 10)

Pink massive pegmatite comprises almost 5 percent of the exposed bedrock in the area, occurring as large dykes, sills and larger crosscutting bodies. These posttectonic pegmatites comprise quartz and

perthitic feldspar in crystals up to 1 m long, most of which is graphically intergrown with quartz. Although the pegmatite is generally leucocratic, some areas may be found which are relatively rich in muscovite, biotite and garnet . Uraninite is also a common but minor accessory. A zone of relatively large pegmatite intrusions about 1 km wide extends northeastward across Drope Lake, slightly oblique to regional foliation.

Mylonitized and augened pegmatitic layers occurring in some of the other gneisses are thought to represent an earlier and transposed generation of pegmatite. Some slightly foliated pegmatitic veins are synkinematic and perhaps represent the earliest pegmatite related to the massive pink pegmatite.

## Tectonic Units (Units 11 to 13)

Three distinctive tectonic units have been recognized. The units largely contain highly deformed equivalents of the other units, as well as some other distinctive rock types.

### Drope Lake "Melange" (Unit 11)

This unit is exposed on the islands along the west shore of Drope Lake and comprises psammitic gneisses with large blocks and smaller inclusions of ultramafic rock. In exposures on the islands just south and west of the largest island in Drope Lake, the rocks are only moderately deformed, presumably due to location in the pressure shadow of a large ultramafic block 250 m in size which makes up the large island. The psammitic gneiss comprises a matrix of plagioclase-quartz-biotite and ultramafic to mafic clasts ranging from centimetre-sized angular fragments up to ellipsoidal blocks 2 m long . The geochemistry of an ultramafic block (J85-177D) and the psammitic matrix (J85-177B and C) are given in Table 1. In other areas the psammitic unit is much more deformed and the ultramafic clasts occur as lenses and boudinaged layers. The injection of granodioritic sheets and conformable leucosomes has further destroyed original relationships. The unit is probably continuous with the zone of ultramafic exposures in Drope Lake.

The unit has features very similar to those developed in a metamorphosed melange unit in North Carolina (Horton et al., 1986).

### Nistowiak Gneisses (Unit 12)

The Nistowiak Gneisses are a group of highly strained plutonic rocks exposed at Nistowiak Lake (Lewry, 1984; Lewry and Slimmon, 1985). In the map area the outcrop pattern is complex, probably reflecting large-scale isoclinal folding of the Nistowiak Lake Shear Zone. Although inhomogeneous and well-layered on the mesoscopic scale, the Nistowiak Gneisses appear to be derived by the extreme deformation and mylonitization of pre-existing granodioritic, granitic and migmatitic precursors.

The gneisses contain 5 to 10 percent rounded to ellipsoidal amphibolitic to gabbroic xenoliths and layers. In many cases the xenoliths appear to have rolled during deformation, as isoclinal folds in the layering are wrapped around them. Smaller rounded dark green to black hornblendite xenoliths are also present, possibly products of metamorphic segregation. The gneisses generally show small-scale isoclinal folds, but axial planar foliation is only locally developed. Refolded isoclines and chaotic folds are also common.

Feldspar crystals with a maximum dimension of several centimetres, comprising as much as 10 to 15 percent of the rock, are interpreted as the deformed remnants of leucosomal sheets and early porphyroblasts. Hornblende porphyroblasts up to 10 mm in size make up as much as 5 percent of the rock, and are mostly randomly oriented. A strong mylonitic fabric is apparent, and preliminary petrographic observations suggest the rocks are strongly recrystallized.

On the western shore of Nistowiak Lake, a complete sequence from moderately deformed granodiorite to intensely deformed porphyroclastic and xenolithic gneisses can be traced eastward. The transition occurs across a zone approximately 250 m wide. Porphyroclastic pelitic gneisses, as well as pink streaky grey intensely laminated granitic rocks also crop out in north-northeast-trending bands.

### Guncoat Gneisses (Unit 13)

Deformed migmatitic psammitic and pelitic gneisses with abundant plagioclase porphyroclasts, similar to those termed the Guncoat Gneisses by Lewry (1984), are present just east of the map area. Conformable tonalitic leucosomal pods several metres long and up to 50 cm wide occur in several exposures. A geochemical analysis of a muscovite-garnet-sillimanite-bearing leucosome (J85-37) is given in Table 1.

## Structure and Deformation

In the Nistowiak Lake area the interpretation of the deformational history is inhibited by lack of primary structures, lithostratigraphic continuity, metamorphic overprint, anatexis and the complexity of the deformation itself.

The dominant structural element in the area is a transposed foliation surface in which lithogical layering, gneissosity (diffuse hand specimen-scale banding) and foliation (surfaces of mineral-preferred dimensional orientation) all generally lie parallel. Apart from in the late

granite and pegmatites (Units 9 and 10), this surface generally strikes northeasterly to north-northeasterly on the regional scale and dips moderately to steeply northwest or north-northwest, but across Nistowiak Lake and towards the east, the trend is progressively more to the east.

A major northeasterly-closing isoclinal fold with a northeasterly-trending and subvertical axial surface occurs in Nistowiak Lake where it is picked out in pelitic gneisses. This fold is attenuated on the limbs and extremely thickened in the fold hinge near Bowering Island. Other large isoclinal folds occur in the core of deformed rocks occupying the centre of Nistowiak Lake. Fold plunges vary from subvertical to shallow, and one southwesterly-plunging closure has been identified just east of Thorpe Bay. These fold styles broadly epitomize the style for a series of isoclinal folds occurring at all scales down to the intrafolial in the area, and may be collectively referred to as the $D_1$ fold set. Some of these isoclines are defined by dykes, xenoliths and porphyroclast trains. In several locations, mafic layers or dykes occurring in granodioritic gneisses form appressed folds with extremely thin limbs and thick bulbous hinges. The hinges of small- (intrafolial) scale isoclines in places show crosscutting axial plane foliations. Some of the smaller isoclines also show isoclinal refolding, and many are rootless. The isoclinal folds are probably much more common than recognized, as the fold hinges are not everywhere easily identifiable.

The isoclinal ($D_1$) folding is postdated by open to tight folds with subvertical axial planes and moderate plunges towards the northwest, north and northeast. These may correspond to the $D_2$ and $D_3$ of Lewry (1977), which in the Glennie Lake area to the northeast plunge north, or north-northeast and northeast, respectively. Most if not all of these later folds appear to postdate migmatization and movement on the major shear zone. A large domal feature composed of Nistowiak Gneisses is exposed near MacDiarmid Bay and is thought to have been produced by large-scale fold interference, but it is not clear whether this is a $D_1/D_2$ interaction.

Lineations of several types are common in the area, including elongate quartz-feldspar domains or rods, feldpsar augen, quartz ribbons, boudin axes and hornblende elongation. Most lineations plunge moderately north-northeast, although some plunge southwest. Quartz-feldspar rods are most common and are associated with both isoclinal and open folds.

The Nistowiak Gneisses are extremely well layered on the centimetre scale. The layering is defined by variation in mafic content, layer-parallel hornblende blastesis, the abundance of feldspar porphyroclasts and differences in grain size. Layering developed by a combination of the following processes: 1) development of a foliation related to the regional deformation; 2) metamorphic segregation and/or anatexis producing compositional and grain-size variation; 3) transposition of dykes or intrusive sheets; 4) severe attenuation of xenoliths; 5) dismemberment of early isoclinal or chaotic folds during shearing; 6) variations in strain around xenoliths; and 7) development of a strong mylonitic fabric.

Feldspar porphyroclasts up to 3 cm in size are common in the map area, particularly in pelite and psammite where they form up to 30 percent of the rock, and they are also common within the Nistowiak Gneisses. They probably originated by tectonic dismemberment of pre-existing leucosomal or pegmatitic sheets, but a significant number are regarded as porphyroblasts which acted as porphyroclasts during deformation.

A large number of northwest-trending brittle fractures and minor shears were identified. Many contain epidote, quartz and chlorite, and some are lined by fault gouge. A less abundant conjugate set trends northeast. These fractures were utilized during the intrusion of pegmatitic dikes and indicate considerable cooling and uplift before intrusion of the pegmatite, possibly in relation to extension which occurred after relaxation of orogenic stresses.

Early movement took place along a major shear zone in Nistowiak Lake and to the southwest. Rocks in the shear zone are intensely laminated, highly deformed and rich in porphyroclastic feldspars. Rocks along the eastern extension of the Guncoat Thrust (Lewry and Slimmon, 1985) are also highly deformed. Due to the scarcity of primary structures in these zones, strain markers are hard to find, but preliminary investigation of a deformed metaconglomerate/agglomerate 5 km east of the area shows a clast aspect ratio as high as 90:1.

## Metamorphism

The area appears to have undergone upper amphibolite facies metamorphism, as judged by the widespread occurrence of migmatite, the general absence of muscovite and the presence of sillimanite. Granulite facies conditions may have been reached locally, as orthopyroxene has been tentatively identified in leucosomal anatectic bodies in the hornblende-plagioclase-diopside gneisses. Metamorphic grade is possibly lower to the east where many of the mafic rocks contain chlorite, although, as pointed out by Winkler (1979), Mg-rich chlorite can, under the proper conditions, be stable at fairly high temperatures. No "high-pressure" minerals such as kyanite have been identified.

Textures preserved in some deformed migmatitic gneisses are suggestive of melt-enhanced deformation. Furthermore, the disruption and folding of leucosomal sheets in pelitic rocks suggest

that at least some of the movement along the Nistowiak Lake Shear Zone postdates anatexis. Mylonitic fabrics produced in some of the deformed rocks, however, are overprinted by recrystallization, indicating the persistence of conditions of high-grade metamorphism or multiple events.

Hornblende porphyroblasts averaging 5 mm in length are very common in the intermediate plutonic rocks and Nistowiak gneisses, commonly making up as much as 5 percent of the rock. Preferred orientation of the hornblendes is rare, suggesting that hornblende blastesis accompanied a later static period of metamorphism. The presence of garnet within pelitic, amphibolitic and mafic plutonic rocks appears to have no simple relationship to metamorphism. Rounded garnets are common in porphyroclastic pelitic gneisses and are thought to have rolled during deformation. A well-defined garnet lineation was observed in at least one outcrop. In some migmatitic plutonic rocks, such as the "tiger gneiss", garnet porphyroblasts occur in both the leucosome and paleosome. Garnet has probably grown at various times throughout the metamorphic and deformational sequence.

## Quaternary Geology

Almost no surficial glacial deposits are present in the area, although a large number of erosional features, including striations and large grooves, are preserved on outcrop surfaces. Measurements of these features indicate ice movement was approximately 210±10° throughout the area, agreeing well with many of the map-scale erosional features such as the trend of Bliss Bay within Drope Lake. Ice movement was subparallel to regional structure throughout the area. On the west shore of Nistowiak Lake, a 500 m long beach is composed of alternating quartzofeldspathic and lavender garnet layers. The sand is derived locally from erosion of the abundant pelitic rocks that crop out in the general vicinity.

## Economic Geology

A badly weathered friable calc-silicate unit comprising quartz, feldspar, carbonate, sulphides and what appears to be molybdenite was identified at one locality on the shore of Nistowiak Lake and on one island in the lake. The unit is about 10 m wide and contains an average of about 2 to 3 percent of the suspected molybdenite, while exceptional patches contain as much as 15 percent. A bright lime green lichen favours this rock and could serve as a useful stratigraphic marker if exposed in other areas.

Uraninite crystals up to 2 cm across are common in massive pegmatites in the area, and have even been observed near the rapids at Leisure Lodge. The west arm of Nistowiak Lake (known as Drope Lake) contains many blast sites and trenches exposing uraniferous pegmatite and an abandoned mine dating from the fifties and sixties (Assessment Files[1] 73P08-0004 and -0033). Other blast sites in the map area, located in hornblende-plagioclase and psammitic gneisses, contain small amounts of visible pyrite and marcasite.

## Summary

The oldest rocks in the Nistowiak Lake area appear to be a sequence of supracrustals consisting of mafic to intermediate metavolcanics, calc-silicate rocks, pelites, psammites and minor marble. Some psammitic gneisses include tectonic fragments of ultramafic rocks in an apparent melange. These rocks are intruded by plutons ranging from gabbro to granodiorite. All of these rocks were metamorphosed to upper amphibolite facies and isoclinally folded; some were also migmatized. Early deformation related to the Nistowiak Shear Zone was concentrated in plutonic and migmatitic rocks. The shear zone was isoclinally folded during later deformation, obscuring its regional significance. Later open folding occurred along northwest-, north- and northeast-trending axes. The final event in the area was the intrusion of massive pegmatite, partially utilizing late northwest-trending brittle fractures. Molybdenite occurs in some of the calc-silicate rocks, and uraninite is fairly common in some of the late pegmatites.

## Acknowledgments

We would like to thank our hosts Nick and Dorothy Fedun and Joe and Jean Hollowaty for all their help and making our summer most enjoyable. We were visited in the field by Pat Bickford (University of Kansas), John Lewry (University of Regina), Bob Macdonald (Saskatchewan Geological Survey), Dave Thomas (Saskatchewan Geological Survey) and Doug Walker (University of Kansas). These people are thanked for their interest and input. A special thanks goes to John Lewry for suggesting the study and introducing the senior author to the field area in August 1985. The residents of Nistowiak Lake are thanked for sharing information on the history, geology and navigation of the Churchill River. This study was supported by the Saskatchewan Geological Survey, a Grant-in-Aid research award from the Sigma Xi Society and NSF Grant 83-13167 to M.E. Bickford and W.R. Van Schmus.

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Project 8609B

# Lake Sediment Gold Anomalies: Follow-up Survey

by M.W. Thomas[1]

Thomas, M.W. (1986): Lake sediment gold anomalies: follow-up survey; in Summary of Investigations 1986, Saskatchewan Geological Survey; Saskatchewan Energy and Mines; Miscellaneous Report 86-4.

The Geological Survey of Canada has performed regional geochemical lake sediment surveying in northern Saskatchewan since 1974 (Hornbrook et al., 1975, 1977; Hornbrook and Garrett, 1976) and recently, with an upsurge in precious metal exploration activity, gold was added to the metal suite being analyzed (Hornbrook et al., 1985). Follow-up geochemical studies in selected areas with coincident anomalous gold in lake sediment and favourable geology have also been undertaken, with results pending (Schmitt, 1985). However, other gold ± base metal anomalies identified from the regional surveys are not related to areas of known mineralization and are not readily explained. This spring the author was contracted by Saskatchewan Energy and Mines to conduct follow-up geochemical sediment sampling in five such areas in an attempt to replicate and further delineate the GSC regional anomalies and, if warranted, to conduct ground geological investigations in the geochemically anomalous areas. This report presents the follow-up geochemical lake sediment gold results for the five areas. A more comprehensive report including other metal distributions is to be produced as a Saskatchewan Energy and Mines open file in the near future.

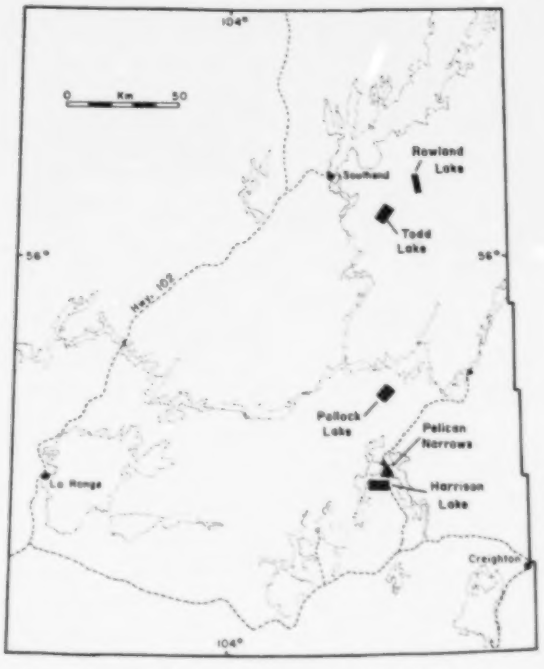


Figure 1 - Locations of follow-up geochemical lake sediment surveys.

## Follow-up Geochemical Lake Sediment Survey

Regarding the GSC regional geochemical lake sediment results, the five areas chosen for follow-up work (Fig. 1) can be summarized as follows:

1) Pelican Narrows (NTS 63M/2) - one site with 31 parts per billion (ppb) Au.
2) Harrison Lake (NTS 63M/2) - four sites with ≥ 5 ppb Au plus other As, Cu, Pb and Ni anomalies.
3) Pollock Lake (NTS 63M/7) - three sites with ≥ 6 ppb Au plus other As anomalies.
4) Todd Lake (NTS 64D/2) - three sites with ≥ 7 ppb Au plus other As, Cu, Pb, Ni and Mo anomalies.
5) Rowland Lake (NTS 64D/7) - two sites of 12 ppb and 32 ppb Au.

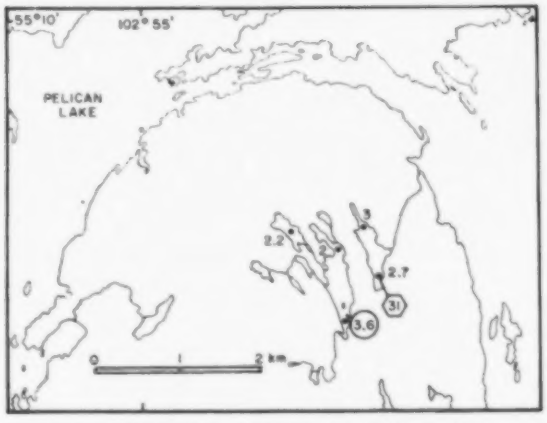


Figure 2 - Gold in lake sediments (in ppb), Pelican Narrows, NTS 63M-2. GSC regional survey results indicated by hexagons; "anomalous" follow-up survey results greater than 3.3 ppb indicated by circles.

[1]Consultant, Regina, Saskatchewan.

Project funded under the Saskatchewan component of the Canada-Saskatchewan Subsidiary Agreement on Mineral Development 1984-89.

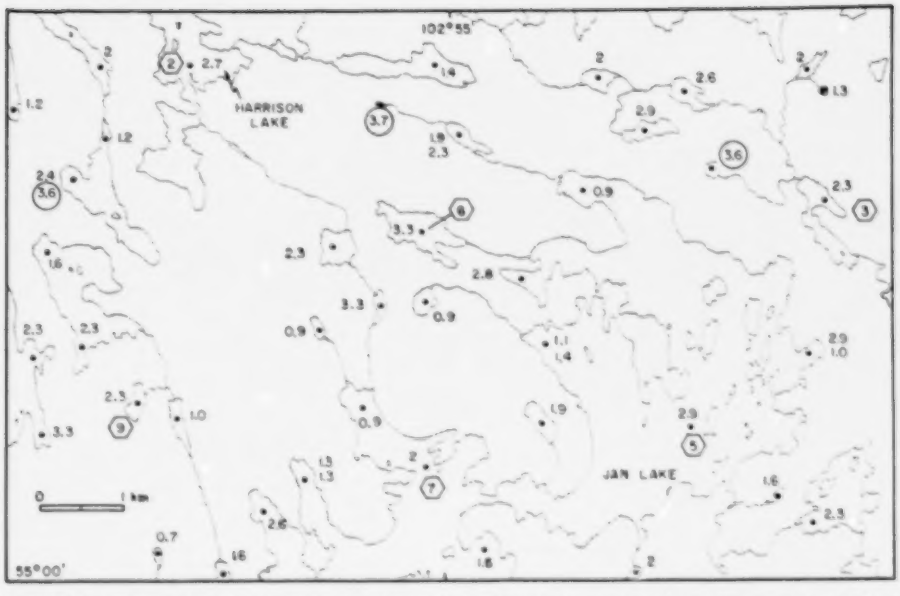


Figure 3 - Gold in lake sediments (in ppb), Harrison Lake, NTS 63M-2. GSC regional survey results indicated by hexagons; "anomalous" follow-up survey results greater than 3.3 ppb indicated by circles.

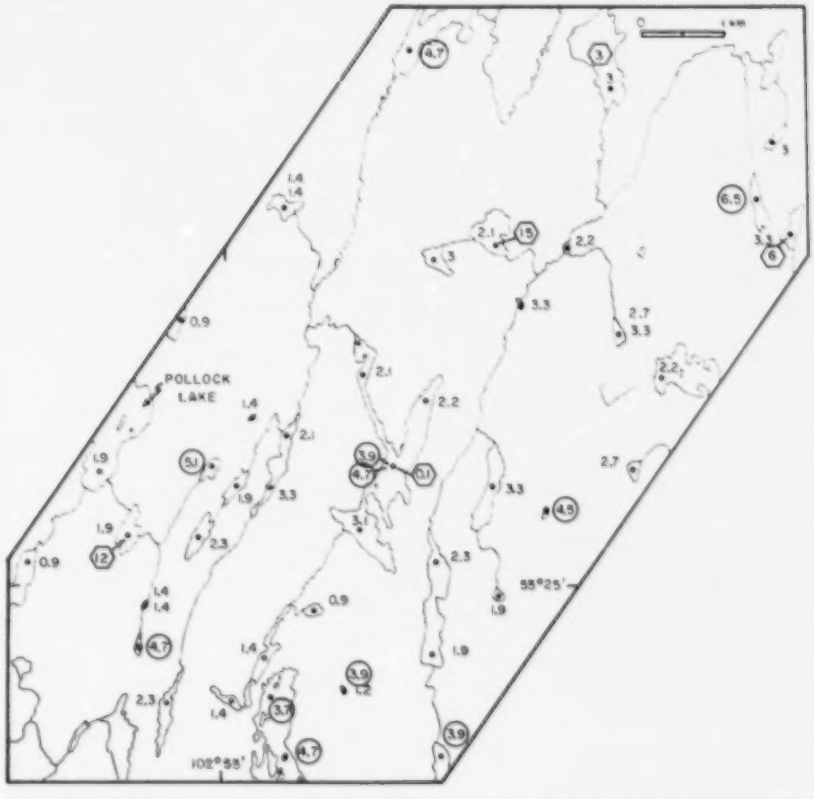


Figure 4 - Gold in lake sediments (in ppb), Pollock Lake, NTS 63M-7. GSC regional survey results indicated by hexagons; "anomalous" follow-up survey results greater than 3.3 ppb indicated by circles.

Lake sediment sampling in these five areas was conducted from June 12 to 14, 1986 utilizing a float-equipped Bell 206 helicopter; sampling procedure and field data collection followed methods used by the GSC. Lake bottom sediment samples were collected at a density of approximately 1 site per $km^2$ (as compared to 1 site per 6 $km^2$ for the GSC regional survey), with field duplicates collected at approximately every tenth site. A total of 157 samples were collected from 142 sites. All lakes sampled by the GSC were resampled. The Saskatchewan Research Council in Saskatoon carried out sample preparation and geochemical analysis for Au, Zn, Cu, Pb, Ni, Co, Ag, Mn, Mo, As, Fe and loss on ignition. Both sample preparation and analytical procedures employed by the Research Council differ in some respects from methods used for the GSC regional surveys. It was hoped that any meaningful metal anomalies would transcend the varying laboratory procedures.

## Gold Geochemical Results - Discussion

Gold geochemical results from both the follow-up survey and the GSC regional survey are presented in Figs. 2 to 6. For the follow-up survey, gold values range from 0.7 to 11.0 ppb; the arithmetic mean is 2.1 ppb and standard deviation is 1.337.

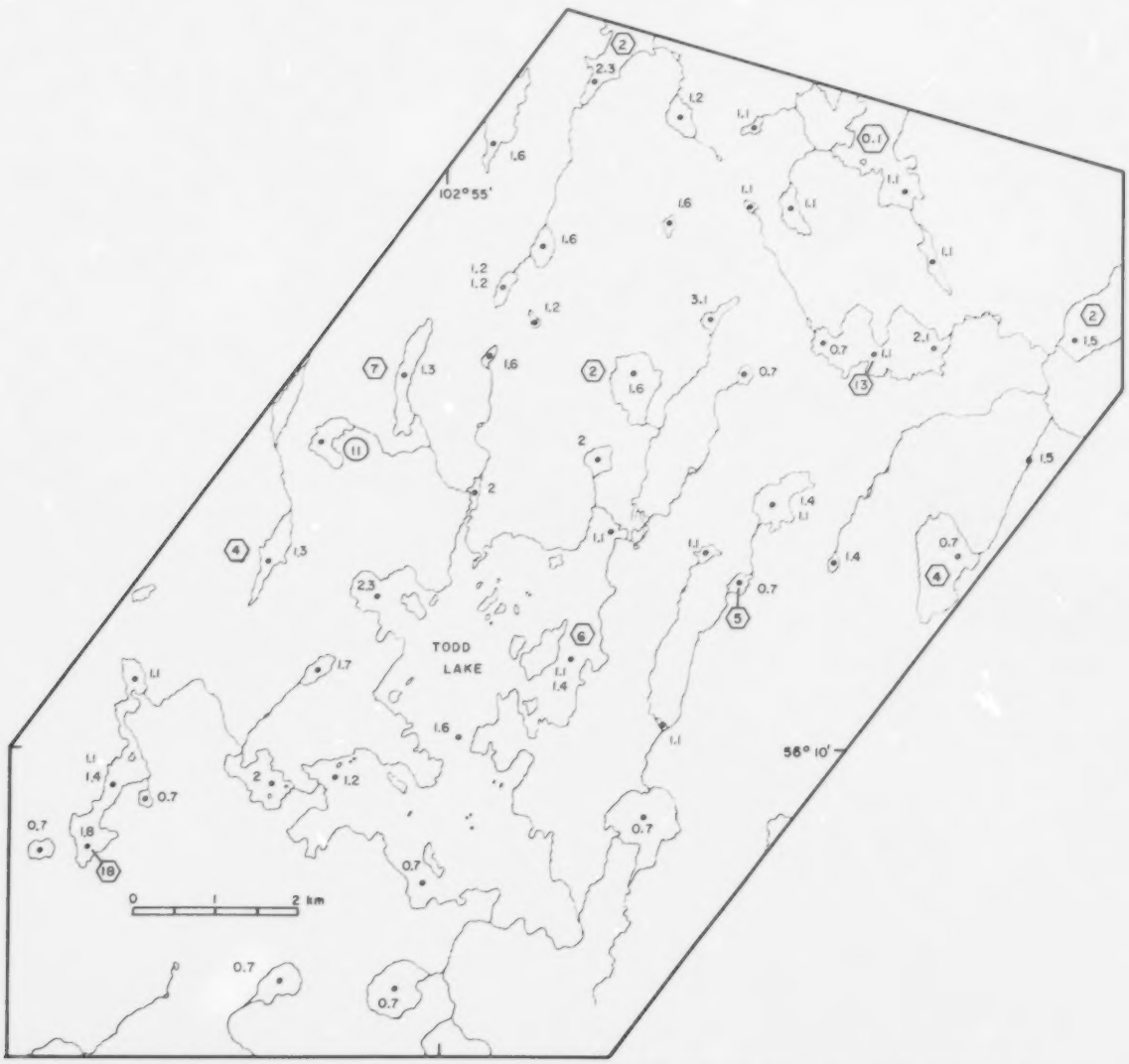


Figure 5 - Gold in lake sediments (in ppb), Todd Lake, NTS 64D-2. GSC regional survey results indicated by hexagons; "anomalous" follow-up survey results greater than 3.3 ppb indicated by circles.

Examination of the geochemical results in Figs. 2 to 6 reveals that correlation of absolute gold values between the two surveys is poor. For lakes sampled by both the regional and follow-up survey, analyses sometimes differ by an order of magnitude; with four exceptions, the regional survey analyses are the higher of the two. If, for the follow-up survey data, the mean plus one standard deviation (i.e., 3.4 ppb Au) is considered to be anomalous, the two surveys can be roughly compared on an anomalous/non-anomalous basis. However, correlation is still poor. High gold results from the regional survey are not duplicated in the follow-up work.

It is possible that the differing sample preparation and gold analytical procedures utilized by the two surveys are causing or contributing to the discrepancies between gold analyses of replicate samples. Since the regional survey results are almost exclusively the higher of the two, different laboratory methods may be suspect. However, inspection of the analytical data shows that the degree of difference in gold values from replicate samples varies widely. The discrepancy appears to be more than a simple 'scale problem'. The possibility that particulate gold is inhomogeneously distributed within a lake basin, and could thereby cause irregular analytical variations between replicate samples, would severely hamper interpretation of gold geochemical results from lake sediment surveys. The problem remains unresolved.

The analytical data and sample pulps as well as lake water samples collected during the follow-up survey have been forwarded to H.R. Schmitt of the GSC for use in his continuing studies of metal distribution in the lake sediment environment. At this time, no ground follow-up work is deemed warranted in any of the five areas surveyed.

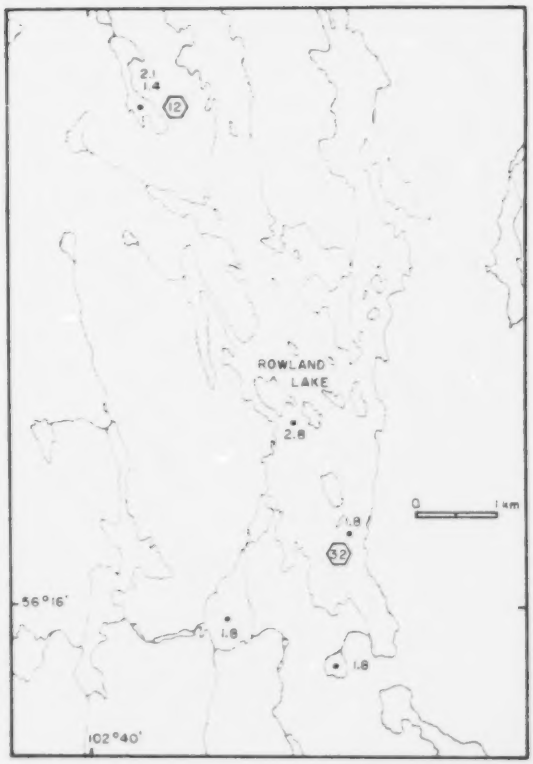


Figure 6 - Gold in lake sediments (in ppb), Rowland Lake, NTS 64D-7. GSC regional survey results indicated by hexagons; "anomalous" follow-up survey results greater than 3.3 ppb indicated by circles.

Acknowledgments

The author would like to thank pilot H. Krausher and sampler J. Argue for their efforts during the follow-up survey.

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Project 8621

# Geochemistry and Geochronology of Metavolcanic and Plutonic Rocks in the Central Metavolcanic Belt

by B.R. Watters[1]

Watters, B.R. (1986): Geochemistry and geochronology of metavolcanic and plutonic rocks in the Central Metavolcanic Belt; in Summary of Investigations 1986, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 86-4.

The geochemical study of metavolcanic and plutonic rock units in the Central Metavolcanic Belt of the La Ronge Domain was carried out in conjunction with field investigations by C.T. Harper and D.J. Thomas (this volume). As the metavolcanic rocks have now been studied extensively, recent research has paid more attention to the intrusive rocks.

## Geochemical Analyses and Data Processing

Major and trace element data have been obtained for a further 297 samples from the central La Ronge Domain, bringing the total number of samples analyzed for this project to 423. Although the rock types analyzed include metalavas and intrusives with minor metasedimentary/ metavolcaniclastic and mineralized varieties, a substantial proportion of the new analytical data are for intrusive rocks in the Star Lake - Bervin Lake area. All samples have been analyzed for Si, Ti, Al, Fe, Mn, Mg, Ca, K, Na, P and LOI, and most of them have also been analyzed for Rb, Sr, Zr, Y, Nb, Pb, Th, Ni, Cu, Zn, Ba, Co, Cr, V, La, Au, As, Ag, Mo, Cd and Be. Twenty-nine samples of metavolcanic and intrusive rocks have been analyzed for the rare earth elements (REE) and Hf, Ta, Cs, Th, U and Sc, while analysis of a further 30 samples for these elements is in progress.

Suites of rocks from the Star Lake and Gibbons Lake Plutons have recently been analyzed for Sr isotopes in collaboration with R.L. Armstrong of the University of British Columbia. The results of this work are reported here.

The geochemical data from this project supplement results from previous studies (Watters, 1981; Watters, 1984; Watters and Armstrong, 1985; Watters and Pearce, 1986), which include Sr isotope data for three metavolcanic suites, and major and trace element data for approximately 185 rocks (mainly metavolcanics), of which 35 were also analysed for REE.

As reported in Watters (1985), all geochemical data for this project, as well as other relevant data from the literature, are presently stored in a Hewlett-Packard microcomputer system developed by the author specifically for the project.

## Metavolcanic Rocks

Geochemical evidence from the metavolcanic rocks points to a volcanic arc setting for the evolution of the La Ronge Domain (Watters, 1981; Watters, 1984; Watters and Armstrong, 1985; Harper et al., 1986). Trace element analytical work carried out by the author at The Open University in collaboration with Dr. J.A. Pearce has led to a more refined tectonic interpretation (Watters and Pearce, 1986).

It has been demonstrated that the geochemical characteristics of basaltic rocks from different tectonic settings may be distinguished using discrimination techniques (e.g., Pearce and Cann, 1979; Pharoah and Pearce, 1984), and MORB-normalized geochemical patterns have been used to demonstrate the general volcanic arc affinities of metabasalts from the La Ronge Domain (Watters, 1984).

Geochemical patterns of representative metabasalts from the La Ronge Domain (Fig. 1) closely resemble those of calc-alkaline volcanic arc basalts in exhibiting selective enrichment in Sr, K, Rb, Ba and Th, while Ce, P and Sm show variable degrees of enrichment. Titanium generally has low concentrations relative to both the normalizing composition and Y and Yb which also display typically low abundances. Anomalously low abundances of K and Rb in some of the basalts may be attributed to a high mobility of these elements during regional metamorphism.

While the patterns of La Ronge metabasalts display strong general similarities to those of recent calc-alkaline volcanic arc basalts, in detail considerable variation exists in the overall distribution of the elements Nb, Ce, P, Zr, Hf, Sm and, to a lesser degree, Ti. Some metabasalts show low abundances of these elements (except for Ce

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Project contracted to the University of Regina with funds provided under the Saskatchewan component of the Canada-Saskatchewan Subsidiary Agreement on Mineral Development 1984-89. Some of the analytical work was funded by a research grant from the Saskatchewan Research Council.

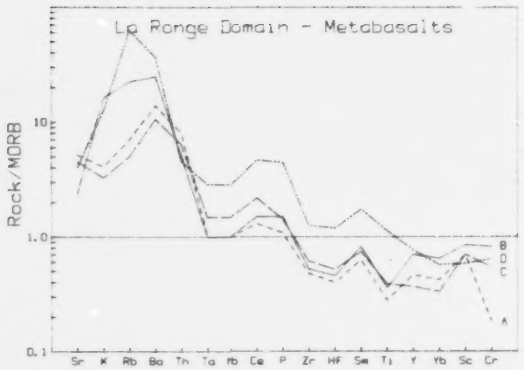


Figure 1 - MORB-normalized geochemical patterns for metabasalts from the La Ronge Domain. Samples C and D are from the Waddy Lake area, samples A and B are from other areas in the Domain. Normalizing values are from Pearce (1982).

and P) and can be interpreted as calc-alkali basalts of oceanic arc affinity (samples A and B, Fig. 1). However, other metabasalts (samples C and D in Fig. 1) are anomalous in being variably enriched in these elements, having patterns characteristic of recent basalts erupted in transitional volcanic arc and continental arc settings (cf. patterns in Fig. 2). Calc-alkaline basalts from these settings usually have a slight 'within-plate' character, indicated by enrichment in Ta, Nb, Zr, Hf and Ti, when compared to calc-alkaline oceanic arc basalts. These characteristics may be due to the involvement of subcontinental lithosphere in the genesis of this magma type. It has been shown by Pearce (1983) that both upper mantle (subcontinental lithosphere) and subduction components can be identified in patterns of basalts from continental margin environments.

Therefore, the composition of metabasaltic rocks strongly suggests that some of the La Ronge magmas evolved in an environment subject to the influence of enriched subcontinental lithosphere, such as beneath a continental margin or in a transitional regime close to continental crust. It is perhaps also significant that the majority of metabasalts having these enriched patterns occur in the Waddy Lake area, where an unusual abundance of felsic volcanic rock is present, including high proportions of rhyolitic volcaniclastics (Harper, 1984, 1985), further suggesting the presence of continental crustal material. There is a similar but lesser development of anomalous basalts in the vicinity of the Churchill River.

Basalts elsewhere in the metavolcanic belt (e.g., Star Lake area) are mainly of typical calc-alkaline oceanic arc character, but some may represent arc tholeiitic types since they have MORB-normalized values of less than unity for the elements Ta, Nb, Ce, P, Zr, Hf, Sm, Ti, Y, Yb, Sc and Cr.

It has been shown by Pearce (1983) that once a volcanic arc character has been established for a suite of basalts, the Zr/Y ratio can provide an effective means of discriminating between oceanic and continental settings. Basalts from continental settings generally have higher Zr/Y ratios because of the Zr derived from an enriched subcontinental mantle source added to the subduction-generated component. The metabasalts from the Waddy Lake area have such continental arc affinities (Fig. 3), whereas metabasalts from other parts of the Central Metavolcanic Belt display dominantly oceanic arc characteristics.

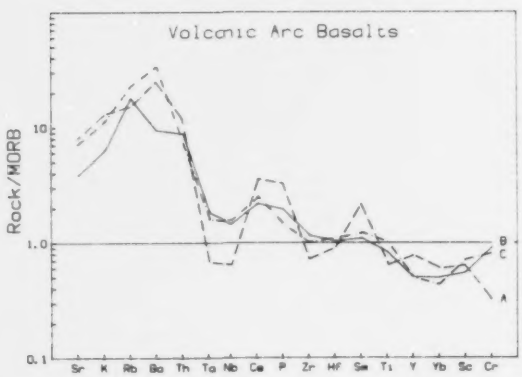


Figure 2 - MORB-normalized geochemical patterns for typical basalts from calc-alkaline oceanic arcs (A), continental margin volcanic arcs (B) and transitional volanic arcs (C). Normalizing values and data sources cited in Pearce (1982 and 1983).

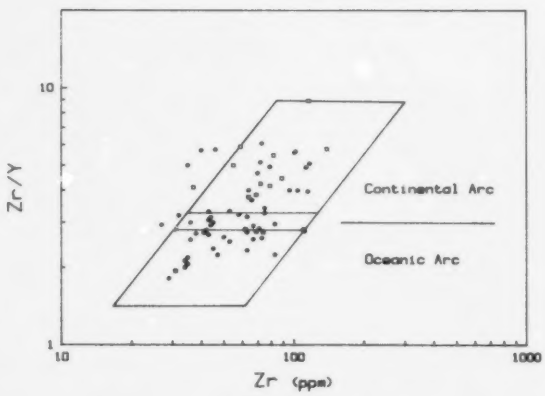


Figure 3 - Zr/Y-Zr oceanic-continental volcanic arc discrimination diagram (Pearce, 1983) for metabasalts from the La Ronge Domain. Open squares, metabasalts from the Waddy Lake area; closed circles, metabasalts from other areas in the Central Metavolcanic Belt.

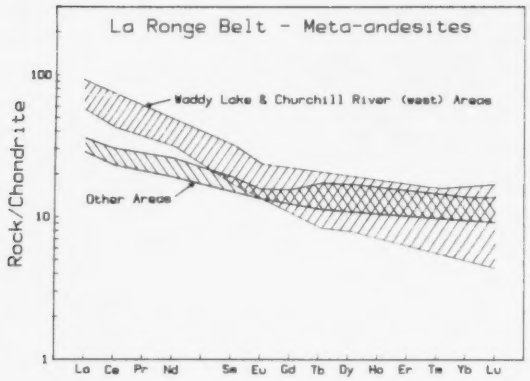
La Ronge Belt - Meta-andesites
Waddy Lake & Churchill River (west) Areas
Other Areas
Rock/Chondrite
100
10
1
La Ce Pr Nd Sm Eu Gd Tb Dy Ho Er Tm Yb Lu

**Figure 4** - Chondrite-normalized rare-earth distribution patterns for meta-andesites from the La Ronge Domain. Chondrite normalizing values from Nakamura (1974).

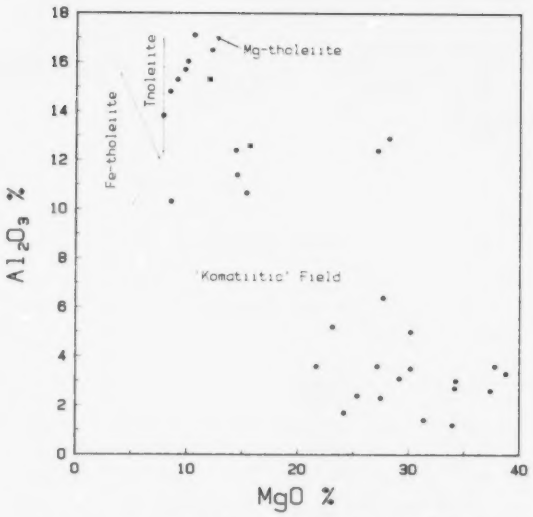


**Figure 5** - Plot of $Al_2O_3$ vs. MgO (after Viljoen et al., 1982) for Mg-basaltic and ultramafic rocks from the southern end of Lower Waddy Lake.

The La Ronge metavolcanics typically display moderate total REE contents and LREE/HREE ratios, with little or no Eu anomaly (Watters, 1985; Watters and Pearce, 1986). While some of the relatively flat REE patterns shown by some metabasalts (e.g., in the Star Lake area) may patterns are typically those of represent island arc tholeiites (Watters, 1985), the majority of calc-alkaline volcanics of oceanic arc character (Bailey, 1981; Jakes and Gill, 1970). However, metavolcanics from the Waddy Lake and Churchill River (west) areas have a distinctly more fractionated and REE-enriched character than metavolcanics from other parts of the belt (Fig. 4). While still typically of calc-alkaline volanic arc character, these LREE-enriched patterns are similar to those displayed by volcanic rocks from transitional or continental volcanic arc settings, a suggestion that is consistent with the evidence provided by the geochemical patterns discussed above.

## Ultramafic and Mg-Basaltic Rocks in the Lower Waddy Lake Area

Magnesium-rich rocks of possible extrusive character (Fox and Johnston, 1980; Harper, 1985) in the southern part of the Lower Waddy lake area are associated in the field with intrusive ultramafic units (Harper, 1984, 1985). A plot of $Al_2O_3$ vs. MgO (Fig. 5) indicates that these rocks comprise three distinct compositional groups, rather than the continuum of types that was previously thought to exist (Watters, 1985):

1) Units that may represent extrusives can be classified as Mg-tholeiites, having MgO contents of less than about 13 percent and relatively high $Al_2O_3$, in excess of 13 percent. Rare-earth element data for a single sample of Mg-basalt provide a chondrite-normalized profile typical of some peridotitic komatiites, having low total REE contents, relative depletion in the light REE and fairly constant heavy REE-normalized concentrations. This categorization is by no means certain as it is not a typical peridotitic komatiite, having, for example, relatively high $Al_2O_3$ and low MgO. Such REE patterns, furthermore, are not unique to komatiitic rocks; certain oceanic basalts have very similar distributions of REE (Saunders, 1984).

2) A second set of samples from an intrusive body showing well-developed primary igneous layering defines another group with a fairly limited range of $Al_2O_3$ (about 10 to 13 percent) but a wide range of MgO (from about 10 to 30 percent). These compositional characteristics suggest that variations in mafic minerals are largely responsible for the range in composition.

3) The third compositional grouping comprises altered ultramafic rocks which belong to, or are associated with, the Red Hill intrusion (Harper, 1985). These rocks have very high MgO contents, ranging from about 20 to 40 percent with $Al_2O_3$ levels of less than 7 percent. The data points show a considerable amount of scatter on the plot (Fig. 5), possibly indicating a suite of peridotitic to dunitic rocks. The highly altered state of the rocks (serpentinized) suggests also that at least some of the compositional variation is due to element mobility during alteration.

The tectonic affinity and relationship of these mafic-ultramafic rocks to the La Ronge metavolcanic sequence are still unresolved.

A detailed geochemical study is in progress and it is expected that further trace element (including REE) data will lead to a clearer understanding of their nature and origin.

Intrusions in the Star Lake - Bervin Lake Area

Detailed geochemical studies are in progress on the major plutons in this part of the La Ronge Domain. The discussion and geochemical plots that follow are based primarily on these new data. The investigation of the Star Lake Pluton is well advanced, while studies of the other plutons (Island Lake, Gibbons Lake, Ismond Lake, Bervin Lake, Roundish Lake, Wilson Lake, Neyrinck Lake) are still in the early stages. A clear picture of both local and regional compositional trends is beginning to emerge from the limited data yet available. For the locality of these plutons, refer to Thomas (1985).

Star Lake Pluton

The Star Lake Pluton is calc-alkaline and displays a marked zonation in major rock types, ranging in composition from gabbro-diorite in the marginal zone to quartz diorite-monzonite-granodiorite in the 'middle' zone and granite in the central zone. Silica contents range from a minimum of about 47 percent in some outer zone rocks to a maximum of about 74 percent in the most felsic granite of the central zone. Models for the origin of the zoning have been previously discussed (Watters, 1985; Harper et al., 1986), and both field and geochemical evidence best support the hypothesis of successive injections of magma, ranging from early basic to later felsic, derived mainly from a larger differentiating magma body at depth. Parent magmas were probably generated by partial melting in the root zones of the La Ronge arc complex and, in a regional context, variations in composition can be explained by varying degrees of partial melting.

Recent geochemical work has added a wealth of data to that previously available, leading to a clearer understanding of the compositional characteristics of the pluton and providing support to previously expressed ideas concerning the origin of the intrusion.

An AFM plot (Fig. 6) shows clearly the calc-alkaline character of rocks from all zones of the pluton. The subdivision of samples into the various zonal types is based primarily on field interpretation (D.J. Thomas, pers. comm.). Basic-intermediate rocks of the outer zone are compositionally much more variable than those of the middle and central zones which show a very tightly constrained compositional trend. The scatter of outer zone compositions is consistent with observations in the field that this zone is highly composite or multiphase in nature (Thomas, pers. comm.). These early phases of intrusion likely represent the emplacement of small batches of magma produced during the initial stages of partial melting in the root zones of the La Ronge arc. During the early stages of this process, melting would have been patchy in distribution and magma compositions locally variable due to variations in source rock composition. Injection of these magmas into the site of the Star Lake body could, therefore, be expected to produce a distribution of rock types as seen in the outer zone, having generally similar basic calc-alkaline chemical affinities but showing some compositional variability. Fractional crystallization was probably not an important process at this stage.

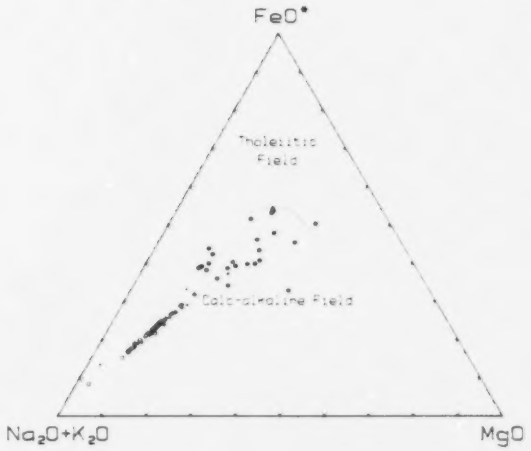


Figure 6 - AFM plot for rocks from the Star Lake Pluton. Full circles, outer zone; crosses, 'middle' zone; open circles, central zone. Field boundaries from Irvine and Barager (1971).

More advanced stages of melting would have homogenized the magma batches, and the very narrow compositional trend displayed by rocks of the middle and central zones is consistent with fractional crystallization of a large magma body with periodic injections of magma into the site of the pluton, partly displacing the earlier more basic phases. Evidence for this sequence of intrusion is found in xenoliths of the earlier basic material in the middle zone rocks (Thomas, pers. comm.). Rocks of the middle and central zones display fairly wide ranges in composition with some overlap, suggesting that these zones may also be considerably more composite or multiphase in character than is apparent from the field evidence.

It might be argued that the compositional scatter shown by the outer zone rocks is due to contamination by metavolcanic country rock rather than representing a primary feature. The trace element data suggest, however, that contamination was not a major factor in the evolution of these magmas (Watters, 1985). Furthermore, definite contaminated granite from the adjacent Island Lake Pluton shows different compositional

characteristics to the outer zone rocks of the Star Lake Pluton, having distinctly higher MgO/FeO* ratios. Since similar country rocks would have been assimilated by both intrusions, the effects of the process should be reflected in basic phases having similar compositional character, but such is not the case.

Sr Isotope Data - A suite of seven samples representing all zones of the Star Lake Pluton provides an isochron (Fig. 7) indicating an age of 1823±44 Ma with an initial $^{87}Sr/^{86}Sr$ ratio of 0.7020±0.0002. Although the Sr isotopes may have suffered slight resetting, this result is not significantly different from the U/Pb zircon age of 1852±21 Ma reported for the pluton by Bickford and Van Schmus (1985). The low initial ratio is further evidence of magmatic arc affinities and, therefore, does not contradict an origin for the magmas involving melting within the La Ronge arc. The fact that the isochron is defined by members of all zones of the pluton is supportive of a genetic link between the various magma phases and also suggests intrusion over a relatively short time span.

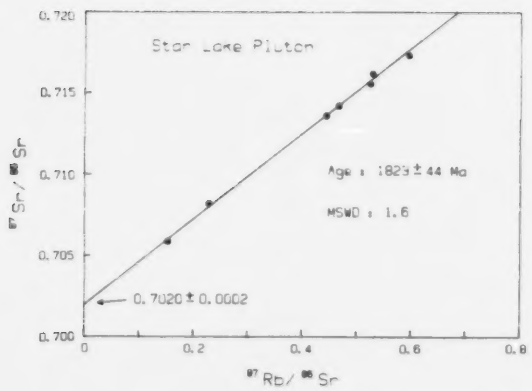


**Figure 7 - Rb-Sr isochron diagram for a suite of rocks from the Star Lake Pluton.**

## Island Lake Pluton

This pluton is essentially homogeneous and compositionally similar to the most felsic core rocks of the Star Lake Pluton (Fig. 8). Silica content in uncontaminated material ranges from about 65 to 72 percent. Trace element geochemistry (Watters, 1985) substantiates this similarity and suggests that the Island Lake magmas may have been even more evolved than those emplaced into the central parts of the Star lake body. The range of compositions found in the Island Lake Pluton is relatively small and indicative of a single injection of magma or multiple injections of magma derived from a restricted source. Those points on Fig. 8 that fall away from the main compositional trend (having variable but lower total

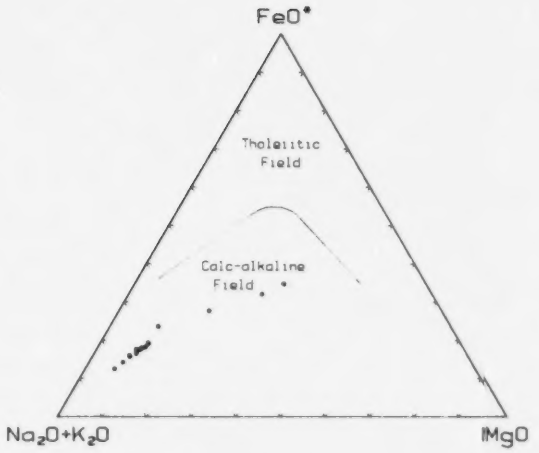


**Figure 8 - AFM plot for rocks from the Island Lake Pluton. Field boundaries from Irvine and Barager (1971).**

alkali contents) represent samples identified in the field as being contaminated (enriched in Fe and Mg). As discussed above, these rocks show a small but significant difference in chemical character to the more basic members of the Star Lake Pluton.

## Gibbons Lake Pluton

The Gibbons Lake Pluton is dominantly intermediate in composition with some basic members. Silica contents of the limited number of

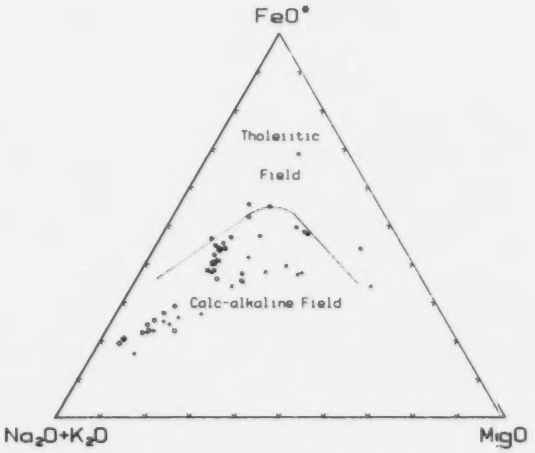


**Figure 9 - AFM plot for rocks from plutons in the Gibbons Lake - Bervin Lake area. Open circles, Ismond Lake Pluton; crosses (+), Bervin Lake Pluton; stars (x), Gibbons Lake Pluton; square, Roundish Lake Pluton; diamonds, Wilson Lake Stock. Field boundaries from Irvin and Barager (1971).**

samples analyzed to date range from about 50 to 66 percent. This pluton would appear to be similar in compositional characteristics (Fig. 9) to the outer zone and, to a lesser extent, the middle zone of the Star Lake Pluton. It has, therefore, a far more restricted range in composition, at the present level of exposure, than the Star Lake body.

### Neyrinck Lake Intrusion

The Neyrinck Lake Intrusion, occurring adjacent to the Gibbons Lake Pluton, is a basic body ($SiO_2$ from about 48 to 52 percent) having some general compositional similarities with the outer zone of the Star Lake Pluton and some of the Gibbons Lake material. The compositions are, however, generally significantly higher in iron (Fig. 9). This intrusion may represent a phase unrelated to the Gibbons and Star Lake plutonism, a view supported by petrography and field evidence (Thomas, pers. comm.).

### Bervin Lake Pluton

Field evidence indicates that the Bervin Lake Pluton includes numerous major phases very similar to those of the Star Lake Pluton, although not having quite such a regular zonal arrangement (Thomas, pers. comm.). The preliminary geochemical work confirms that the compositional trend and range of compositions (Fig. 9) are indeed very similar to much of the Star Lake body. Silica content of the samples analyzed ranges from about 57 to 71 percent; no rocks as basic as some of those in the outer zone of the Star Lake body have yet been identified by geochemistry but few samples have yet been analysed. The Bervin Lake magmas were probably generated and evolved under conditions very similar to the Star Lake magmas and underwent a similar emplacement history. Further detailed major and trace element (including REE) studies are in progress to test this hypothesis.

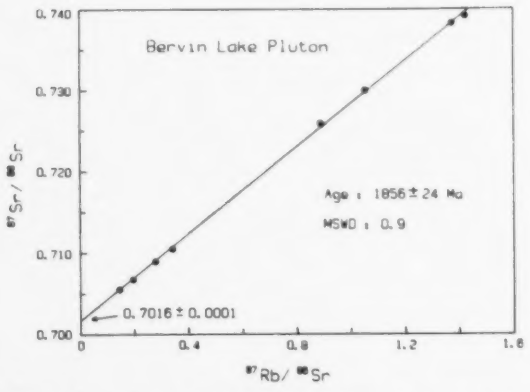


**Figure 10 - Rb-Sr isochron diagram for a suite of rocks from the Bervin Lake Pluton.**

Sr Isotope Data - A suite of eight samples representative of all phases of the Bervin Lake Pluton provides an isochron (Fig. 10) indicating an age of 1856±24 Ma with an initial $^{87}Sr/^{86}Sr$ ratio of 0.7016±0.0001, suggesting that this body is of the same age as the Star Lake Pluton, as well as the majority of other plutons in the Central Metavolcanic Belt (Bickford and Van Schmus, 1985). The low initial ratio once again provides evidence of magmatic arc affinities and is supportive of a magmatic history, as suggested for the Star Lake intrusion. The fact that the isochron is defined by members of all zones of the pluton, even though there is a clear gap in the range of Rb/Sr ratios, generally implies a direct genetic link between the various magma phases and also suggests intrusion over a relatively short time span.

### Ismond Lake Pluton, Roundish Lake Pluton and Wilson Lake Stock

These intrusions are chemically similar to the Island lake Pluton and the central parts of the Star Lake Pluton in that they are dominantly felsic and have a limited compositional range (Fig. 9), as expected from their generally homogeneous character based on field observations (Thomas, 1985). Silica contents are most commonly in the range 68 to 75 percent, with minor intermediate material having $SiO_2$ down to 63 percent.

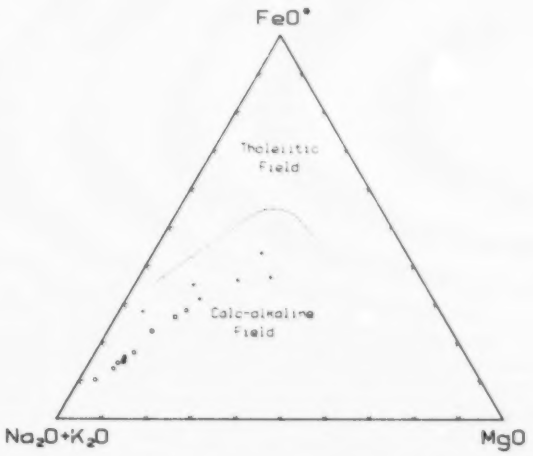


**Figure 11 - AFM plot for rocks from plutons in the Waddy Lake - Tower Lake area. Open circles, Contact Lake Pluton; crosses (+), Boundary Lake Pluton; stars (x), Komis Granite Body; squares, Round Lake Stock. Field boundaries from Irvine and Barager (1971).**

## Plutons in the Waddy Lake - Tower Lake Area

Detailed geochemical studies of selected plutons in the Waddy Lake - Tower Lake area are in progress and only very limited data are presently available. As in the Star Lake - Bervin Lake area, the plutons

are distinctly calc-alkaline (Fig. 11). In terms of alkalies, MgO and FeO*, similar compositional trends and ranges of composition from intermediate to felsic are displayed by the Contact Lake Pluton, the Round Lake Stock and Komis Granite body. From the limited number of samples analyzed to date, the Contact Lake body, however, shows the widest range of $SiO_2$ content, from 66 to 74 percent.

The Komis and Round Lake intrusions may have a far more restricted range of $SiO_2$ (69 to 72 percent), but further work is required before any definite conclusions can be made. Harper (1985) described the Boundary Lake Pluton as petrographically distinctive. Chemically, it would also appear somewhat different to the other plutons discussed above, in that it is generally more basic (relatively low alkalies and $SiO_2$ from 60 to 71 percent) and has a slightly more iron-enriched trend on an AFM plot.

## Tectonic Setting of the Plutons

Using the trace element criteria proposed by Pearce et al. (1984) for discriminating between 'granitic' rocks from different intrusive settings, it was shown that the Star Lake and Island Lake Plutons and plutons from the Waddy lake area can be classified as 'volcanic arc granites' (Watters, 1985). Such an interpretation is entirely consistent with that suggested by the volcanic rock geochemistry and Sr-isotopic characteristics of the intrusions. Recent data for plutons in the Gibbons Lake - Bervin Lake area provide further evidence for the volcanic arc character of granitic plutons in the La Ronge belt (Fig. 12).

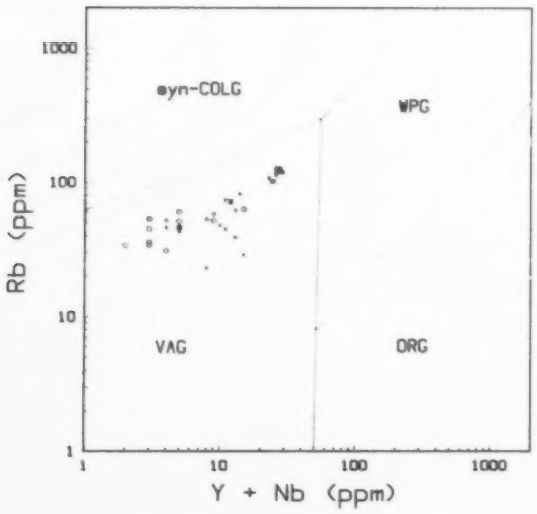


**Figure 12 - Rb vs. Y+Nb discrimination plot for 'granitic' rocks ($SiO_2$ greater than 56 percent) from the Gibbons Lake - Bervin Lake area. Field boundaries are from Pearce et al. (1984). VAG, volcanic arc granites; ORG, ocean ridge granites; WPG, within-plate granites; syn-COLG, syn-collision granites. Open circles, Ismond Lake Pluton; crosses (+), Bervin Lake Pluton; stars (x), Gibbons Lake Pluton; square, Roundish Lake Pluton; diamonds, Wilson Lake Stock.**

## Conclusions

1) Geochemical evidence strongly suggests that the La Ronge volanic arc developed in a transitional environment, for the greater part on oceanic crust but close to a continental margin, extending in some sectors onto thin marginal continental crust. A modern analogy would be, perhaps, the Kurile-Aleutian arc system.

2) The Star Lake Pluton is calc-alkaline with a compositional range from basic to felsic. The middle and central zones define a very tight compositional trend, whereas the outer zone displays greater variability attributable to the multiphase injection of small batches of magma representing the earliest stages of partial melting in the root zones of the La Ronge arc complex. The composition of later phases was probably determined to a great extent by fractional crystallization processes.

3) Geochemistry confirms the classification of 'granitic' plutons in the Star Lake - Bervin Lake area by Thomas (1985) in that: (a) the Star Lake, Gibbons Lake and Bervin Lake bodies are of a similar type, showing wide compositional variation; and (b) intrusions such as the Island Lake Pluton, Ismond Lake Pluton, Wilson Lake Stock and Roundish Lake Pluton are dominantly felsic (to intermediate) and have more restricted compositional ranges.

4) All plutons, whether homogeneous or zoned, were probably formed by the same melting and fractionation processes, as discussed above and in Watters (1985). Differences in compositional structure can be attributed to variations in emplacement sequence as seen at the present level of exposure.

5) Sr-isotopic studies indicate ages of 1823±44 Ma and 1856±24 Ma for the Star Lake and Bervin Lake Plutons, respectively. Low initial ratios are consistent with derivation of the magmas by melting in the roots of the La Ronge arc, and the fact that these isochrons are defined by rocks representative of all zones in these intrusions indicates that all magma phases were genetically linked and were emplaced over a short time span.

6) Plots of geochemical data for plutons from the Gibbons Lake - Bervin Lake area on 'granite' discrimination diagrams provide evidence that these plutons (in addition to the Star Lake, Island Lake and Waddy Lake intrusions) are also of 'volcanic arc' affinity.

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Project 8602

# Kisseynew Metallotect Geochemical Study

by G.R. Parslow[1]

Parslow, G.R. (1986): Kisseynew Metallotect Geochemical Study; in Summary of Investigations 1986, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 86-4.

In 1985 a study of the "Kisseynew Metallotect" (Gale & Ostry, 1984) in Saskatchewan was initiated. The overall objective is to evaluate, using a geochemical approach, the metallotect concept and establish exploration guidelines for base and precious metals in the Kisseynew Domain.

## Update on 1985 Work

During the summer of 1985, a five-man field crew collected some 300 samples of 'metallotect' and associated rocks in the Kisseynew belt of east-central Saskatchewan. Observations regarding the 'metallotect' and its possible structural relationships with the lower grade metavolcanic rocks of Flin Flon and La Ronge were reported upon by Parslow and Gaskarth (1985). The conclusions can be summarized as follows: the 'metallotect' is apparently composed of volcanic or subvolcanic basic to intermediate rocks in which igneous fabrics and/or mineralogy are preserved only rarely; these rocks are bounded above and below by gneissic rocks of possible sedimentary origin; the metamorphic grade is high and it is possible that the whole sequence represents a deeper, and therefore stratigraphically lower(?), portion of the crust than the more typical Amisk Series of rocks to the south.

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Project funded under the Saskatchewan component of the Canada-Saskatchewan Subsidiary Agreement on Mineral Development 1984-89.

## Petrography

Study of thin sections has led to a number of conclusions:

Table 1 - Summary Statistics of 1985 Mari Lake Data (290 Samples)

| | MEAN | S.D. | MIN | MAX | GMEAN | GM-S.D. | GM+S.D. | LOGMEAN | LOG S.D. |
|---|---|---|---|---|---|---|---|---|---|
| SiO2 | 61.25 | 8.84 | 42.80 | 82.39 | 60.62 | 52.43 | 70.09 | 4.1046 | 0.1452 |
| TiO2 | 0.49 | 0.36 | 0.02 | 2.53 | 0.60 | 0.33 | 1.08 | -0.5102 | 0.5941 |
| Al2O3 | 15.45 | 2.78 | 1.00 | 23.64 | 15.13 | 12.10 | 18.93 | 2.7169 | 0.2236 |
| Fe2O3 | 0.60 | 0.30 | 0.05 | 3.65 | 0.70 | 0.39 | 1.25 | -0.3573 | 0.5015 |
| MnO | 0.12 | 0.10 | 0.01 | 1.22 | 0.10 | 0.05 | 0.19 | -2.2891 | 0.6406 |
| FeO | 6.48 | 3.89 | 0.39 | 29.57 | 5.67 | 3.10 | 10.12 | 1.7354 | 0.5794 |
| MgO | 3.71 | 2.79 | 0.12 | 17.85 | 2.81 | 1.24 | 6.39 | 1.0329 | 0.8217 |
| CaO | 6.77 | 4.87 | 1.01 | 22.34 | 5.54 | 2.86 | 10.76 | 1.7127 | 0.6633 |
| Na2O | 2.74 | 1.00 | 0.01 | 5.98 | 2.49 | 1.44 | 4.30 | 0.9107 | 0.5475 |
| K2O | 1.75 | 1.17 | 0.01 | 6.52 | 1.31 | 0.54 | 3.19 | 0.2698 | 0.8900 |
| P2O5 | 0.24 | 0.06 | 0.07 | 0.71 | 0.23 | 0.17 | 0.31 | -1.4871 | 0.3105 |
| H2O- | 0.06 | 0.04 | 0.01 | 0.10 | 0.04 | 0.02 | 0.09 | -3.1074 | 0.7201 |
| LOI | 0.96 | 0.77 | 0.01 | 5.65 | 0.72 | 0.30 | 1.73 | -0.3317 | 0.8776 |
| Ba | 440.41 | 1157.10 | 1.00 | 19286.00 | 179.92 | 27.60 | 1172.77 | 5.1925 | 1.8746 |
| Cr | 159.74 | 298.70 | 1.00 | 2496.00 | 62.95 | 13.80 | 285.53 | 4.1424 | 1.5119 |
| Cu | 42.00 | 75.12 | 1.00 | 1013.00 | 21.14 | 6.52 | 68.53 | 3.0513 | 1.1760 |
| Nb | 7.81 | 2.79 | 1.90 | 19.70 | 7.27 | 4.89 | 10.80 | 1.9839 | 0.3961 |
| Ni | 57.60 | 117.10 | 3.00 | 1055.00 | 29.03 | 10.13 | 87.85 | 3.3955 | 1.0001 |
| Pb | 10.52 | 7.34 | 1.00 | 61.00 | 8.77 | 4.00 | 16.03 | 2.1711 | 0.6032 |
| Rb | 35.71 | 27.74 | 1.00 | 117.00 | 20.90 | 5.75 | 75.90 | 3.0399 | 1.2906 |
| Sr | 301.00 | 162.71 | 17.00 | 1240.00 | 259.60 | 143.25 | 470.45 | 5.5592 | 0.5945 |
| Th | 4.05 | 3.09 | 1.00 | 20.00 | 3.15 | 1.51 | 6.55 | 1.1463 | 0.7339 |
| U | 1.87 | 0.93 | 1.00 | 6.00 | 1.66 | 1.02 | 2.70 | 0.5093 | 0.4056 |
| V | 156.22 | 100.44 | 1.00 | 810.00 | 114.75 | 42.10 | 312.13 | 4.7427 | 1.0007 |
| Y | 22.91 | 8.57 | 7.00 | 60.00 | 21.46 | 14.03 | 31.07 | 3.0664 | 0.3700 |
| Zn | 76.01 | 50.04 | 4.00 | 600.00 | 65.35 | 36.61 | 116.65 | 4.1797 | 0.5794 |
| Zr | 114.81 | 81.20 | 20.00 | 1220.00 | 100.40 | 59.43 | 169.62 | 4.6092 | 0.5243 |
| Au | 4.01 | 14.72 | 0.10 | 222.00 | 1.20 | 0.31 | 5.22 | 0.2452 | 1.4070 |

1) the majority of rocks exhibit metamorphic fabrics;
2) the majority of rocks exhibit an upper amphibolite facies mineralogy that has been overprinted by a retrogressive event;
3) in rare cases, igneous fabrics such as feldspar phenocrysts and rhythmic layering(?) can be identified in 'metallotect' rocks;
4) close to shear zones (e.g., Roberts Bay), the retrogression event has been dramatic (namely, the presence of clinozoisite in calc-silicate rocks at the expense of more typical diopside);
5) evidence of shearing is more prevalent in strain susceptible rocks such as amphibolites and calc-silicates than in the gneisses, etc.; and
6) rocks containing elevated values of gold exhibit evidence of shearing.

## Geochemistry

Initial studies of the chemical data allow the following tentative conclusions to be drawn:
1) from Table 1 it is clear that the Kisseynew rocks are, on average, "basaltic andesites - andesites" (expressed in igneous terms);
2) the amphibolitic rocks exhibit the highest gold values (cf. Tables 2 and 3);
3) granitic rocks exhibit the lowest gold values.

Since the amphibolites are enriched in gold, the initial interpretation is that the 'metallotect' is a real entity; however, as Fig. 1 illustrates, some amphibolites are enriched in gold and others are not. In fact, it transpires that any rock type, even calc-silicate, may or may not be enriched in gold (e.g., samples 177 to 184, from a traverse across the 'metallotect', include three gneiss samples which contain the highest gold values). Conversely, samples from some traverses across typical

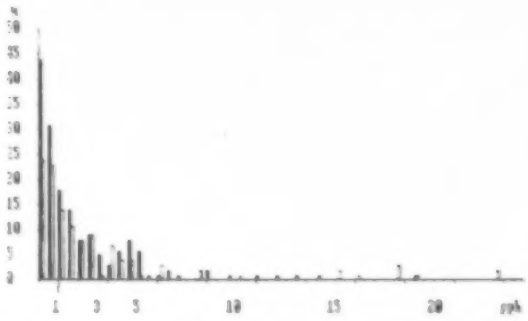


Figure 1 - Histogram of Au values in 'normal' (black) and 'metallotect' (open) rocks of the Mari Lake region. All values above 25 ppb (not shown) are in 'metallotect-type' rocks.

Table 2 - Summary Statistics of Mari Lake Gneisses (94 Samples)

| | MEAN | S.D. | MIN | MAX | GMEAN | GM-S.D. | GM+S.D. | LOGMEAN | LOG S.D. |
|---|---|---|---|---|---|---|---|---|---|
| SiO2 | 65.74 | 6.00 | 49.97 | 82.39 | 65.47 | 59.74 | 71.76 | 4.1816 | 0.0917 |
| TiO2 | 0.60 | 0.17 | 0.22 | 1.13 | 0.58 | 0.42 | 0.79 | -0.5469 | 0.3100 |
| Al2O3 | 15.33 | 2.42 | 8.58 | 23.64 | 15.13 | 12.81 | 17.87 | 2.7165 | 0.1667 |
| Fe2O3 | 0.67 | 0.20 | 0.09 | 1.11 | 0.63 | 0.43 | 0.92 | -0.4664 | 0.3815 |
| MnO | 0.09 | 0.04 | 0.01 | 0.26 | 0.08 | 0.05 | 0.13 | -2.5540 | 0.4747 |
| FeO | 5.39 | 1.60 | 0.75 | 8.99 | 5.09 | 3.48 | 7.43 | 1.6267 | 0.3791 |
| MgO | 2.55 | 1.13 | 0.72 | 8.64 | 2.31 | 1.45 | 3.67 | 0.8363 | 0.4651 |
| CaO | 4.42 | 2.55 | 1.20 | 21.38 | 3.96 | 2.52 | 6.24 | 1.3769 | 0.4538 |
| Na2O | 2.95 | 0.89 | 0.27 | 5.98 | 2.77 | 1.83 | 4.19 | 1.0198 | 0.4140 |
| K2O | 2.02 | 0.79 | 0.18 | 4.00 | 1.79 | 0.99 | 3.26 | 0.5848 | 0.5984 |
| P2O5 | 0.23 | 0.05 | 0.12 | 0.43 | 0.22 | 0.18 | 0.28 | -1.4984 | 0.2242 |
| H2O- | 0.06 | 0.04 | 0.01 | 0.17 | 0.05 | 0.02 | 0.09 | -3.0552 | 0.6977 |
| LOI | 0.83 | 0.52 | 0.18 | 2.71 | 0.70 | 0.39 | 1.26 | -0.3585 | 0.5012 |
| Ba | 493.90 | 217.83 | 1.00 | 1072.00 | 393.88 | 146.73 | 1056.86 | 5.9750 | 0.9872 |
| Cr | 124.41 | 75.93 | 3.00 | 376.00 | 88.31 | 30.14 | 258.76 | 4.4809 | 1.0750 |
| Cu | 27.16 | 23.25 | 2.00 | 186.00 | 18.60 | 7.46 | 46.79 | 2.9274 | 0.9102 |
| Nb | 8.03 | 1.85 | 4.50 | 13.90 | 7.82 | 6.24 | 9.82 | 2.0572 | 0.2267 |
| Ni | 39.81 | 21.58 | 3.00 | 99.00 | 32.16 | 15.06 | 68.67 | 3.4707 | 0.7586 |
| Pb | 11.97 | 7.93 | 5.00 | 61.00 | 10.75 | 7.10 | 16.27 | 2.3748 | 0.4146 |
| Rb | 42.97 | 21.65 | 1.00 | 113.00 | 34.33 | 14.29 | 82.44 | 3.5359 | 0.8762 |
| Sr | 387.11 | 161.85 | 114.00 | 1136.00 | 355.64 | 232.90 | 543.07 | 5.8739 | 0.4233 |
| Th | 4.41 | 2.13 | 1.00 | 11.00 | 3.85 | 2.20 | 6.74 | 1.3478 | 0.5601 |
| U | 1.89 | 0.91 | 1.00 | 6.00 | 1.70 | 1.06 | 2.72 | 0.5282 | 0.4707 |
| V | 132.24 | 60.33 | 5.00 | 255.00 | 111.38 | 54.37 | 228.17 | 4.7129 | 0.7172 |
| Y | 21.06 | 5.91 | 9.00 | 45.00 | 20.29 | 15.38 | 26.76 | 3.0100 | 0.2769 |
| Zn | 74.60 | 50.22 | 9.00 | 463.00 | 64.76 | 37.80 | 110.93 | 4.1707 | 0.5382 |
| Zr | 124.76 | 36.85 | 50.00 | 252.00 | 119.89 | 90.46 | 158.90 | 4.7866 | 0.2817 |
| Au | 2.14 | 2.86 | 0.10 | 19.10 | 1.06 | 0.38 | 3.70 | 0.0536 | 1.2557 |

Table 3 - Summary Statistics of Mari Lake Amphibolites (101 Samples)

| | MEAN | S.D. | MIN | MAX | GMEAN | GM-S.D. | GM+S.D. | LOGMEAN | LOG S.D. |
|---|---|---|---|---|---|---|---|---|---|
| SiO2 | 54.51 | 5.53 | 45.30 | 70.74 | 54.25 | 49.10 | 59.84 | 3.9935 | 0.0981 |
| TiO2 | 0.85 | 0.42 | 0.10 | 2.40 | 0.76 | 0.47 | 1.23 | -0.2722 | 0.4796 |
| Al2O3 | 16.23 | 3.00 | 1.00 | 21.71 | 15.79 | 11.93 | 20.91 | 2.7597 | 0.2086 |
| Fe2O3 | 1.00 | 0.37 | 0.52 | 3.65 | 1.03 | 0.70 | 1.37 | 0.0311 | 0.2037 |
| MnO | 0.10 | 0.13 | 0.05 | 1.22 | 0.16 | 0.11 | 0.25 | -1.8246 | 0.4225 |
| FeO | 0.72 | 3.02 | 4.15 | 29.57 | 0.35 | 6.29 | 11.10 | 2.1225 | 0.2040 |
| MgO | 5.35 | 2.77 | 0.57 | 17.71 | 4.67 | 2.60 | 8.13 | 1.5413 | 0.3549 |
| CaO | 9.39 | 2.79 | 1.09 | 10.43 | 8.02 | 5.95 | 13.09 | 2.1774 | 0.3941 |
| Na2O | 2.39 | 0.95 | 0.01 | 5.37 | 2.09 | 1.03 | 4.26 | 0.7380 | 0.7101 |
| K2O | 1.04 | 0.07 | 0.01 | 4.44 | 0.74 | 0.29 | 1.06 | -0.3011 | 0.9235 |
| P2O5 | 0.26 | 0.00 | 0.14 | 0.60 | 0.25 | 0.19 | 0.33 | -1.4012 | 0.2039 |
| H2O- | 0.06 | 0.04 | 0.01 | 0.10 | 0.05 | 0.02 | 0.09 | -3.0960 | 0.7220 |
| LOI | 1.00 | 0.65 | 0.01 | 3.42 | 0.74 | 0.26 | 2.05 | -0.3074 | 1.0237 |
| Ba | 377.30 | 1940.03 | 1.00 | 19286.00 | 62.91 | 7.26 | 544.76 | 4.1417 | 2.1507 |
| Cr | 213.55 | 405.60 | 1.00 | 2496.00 | 63.21 | 11.25 | 355.22 | 4.1464 | 1.7263 |
| Cu | 60.40 | 115.35 | 4.00 | 1013.00 | 35.51 | 11.70 | 107.74 | 3.5690 | 1.1099 |
| Rb | 7.24 | 3.20 | 1.90 | 16.50 | 6.51 | 4.01 | 10.56 | 1.8720 | 0.4042 |
| Ni | 87.32 | 161.45 | 3.00 | 855.00 | 41.01 | 12.96 | 129.00 | 3.7130 | 1.1522 |
| Pb | 7.56 | 5.53 | 1.00 | 37.00 | 6.20 | 3.45 | 11.40 | 1.0366 | 0.5973 |
| Rb | 17.67 | 21.69 | 1.00 | 107.00 | 0.30 | 2.22 | 31.09 | 2.1163 | 1.3207 |
| Sr | 247.45 | 165.63 | 17.00 | 1240.00 | 202.74 | 101.51 | 404.92 | 5.3119 | 0.6910 |
| Th | 2.53 | 1.05 | 1.00 | 9.00 | 2.00 | 1.02 | 3.94 | 0.6940 | 0.6771 |
| U | 1.73 | 0.04 | 1.00 | 4.00 | 1.55 | 0.90 | 2.47 | 0.4411 | 0.4642 |
| V | 211.04 | 115.55 | 1.00 | 810.00 | 170.99 | 60.00 | 430.00 | 5.1416 | 0.9222 |
| Y | 25.90 | 9.69 | 11.00 | 60.00 | 24.31 | 17.01 | 34.73 | 3.1907 | 0.3569 |
| Zn | 81.69 | 30.24 | 25.00 | 183.00 | 75.79 | 50.43 | 113.90 | 4.3279 | 0.4074 |
| Zr | 106.91 | 125.54 | 20.00 | 1220.00 | 83.05 | 44.05 | 159.59 | 4.4290 | 0.6436 |
| Au | 6.04 | 24.50 | 0.10 | 222.00 | 1.40 | 0.29 | 6.81 | 0.3377 | 1.5011 |

'metallotect' exhibit no gold enrichment (e.g., samples 233 to 237 in South Mari Lake). Thus it is clear that, contrary to the author's previous comments (Parslow and Gaskarth, 1985) the 'metallotect' (sensu stricto) may not in fact exist and strongly enhanced gold values may be due to something other than simple lithological control. The preliminary interpretation is that the 'metallotect' contains a slightly enriched distribution of syngenetic gold and copper (cf. Tables 2 and 3) that has, in places, been concentrated epigenetically, not only in the amphibolites but also in other adjacent rock types. The only correlation of high gold values to any other variable is, at present, the apparent relationship to shear zones (namely the enhanced values in the Roberts Bay area).

Characterization of the rocks on common discriminant diagrams (e.g., Fig. 2) is, at the time of writing, unclear and further study is obviously necessary in order to unravel the "shotgun patterns" observed. The extreme chemical variation of the 'amphibolite' file suggests that some of the rocks are perhaps para-amphibolites or even artifacts of high-grade metamorphism, rather than true 'igneous' rocks. In contrast, the more clearly defined distributions of the gneisses on the diagrams (only one example shown here) is somewhat surprising and suggests that they may be metamorphosed distal volcanics or orthogneisses.

The 1985 results highlight the problems of interpreting geochemical data from high-grade metamorphic terrain. Important conclusions that directed the 1986 program, were that:

1) the 'metallotect' is not a simple unit of igneous rock; its varied chemistry requires explanation;
2) the fact that many 'metallotect' samples contain little gold may reflect the varied chemistry of these rocks;
3) the observation that all rock types can include high gold samples may have a simple statistical explanation (i.e., the high Au values in the calc-silicates may be outliers of a normal Gaussian distribution) or they may be evidence of an epigenetic overprinting of Au related to shearing effects,
4) because samples were rarely collected at intervals of less than 250 m on traverses often several kilometres apart, further detailed sampling of areas of 'metallotect' and associated rocks containing elevated gold values and areas with low gold values was required.

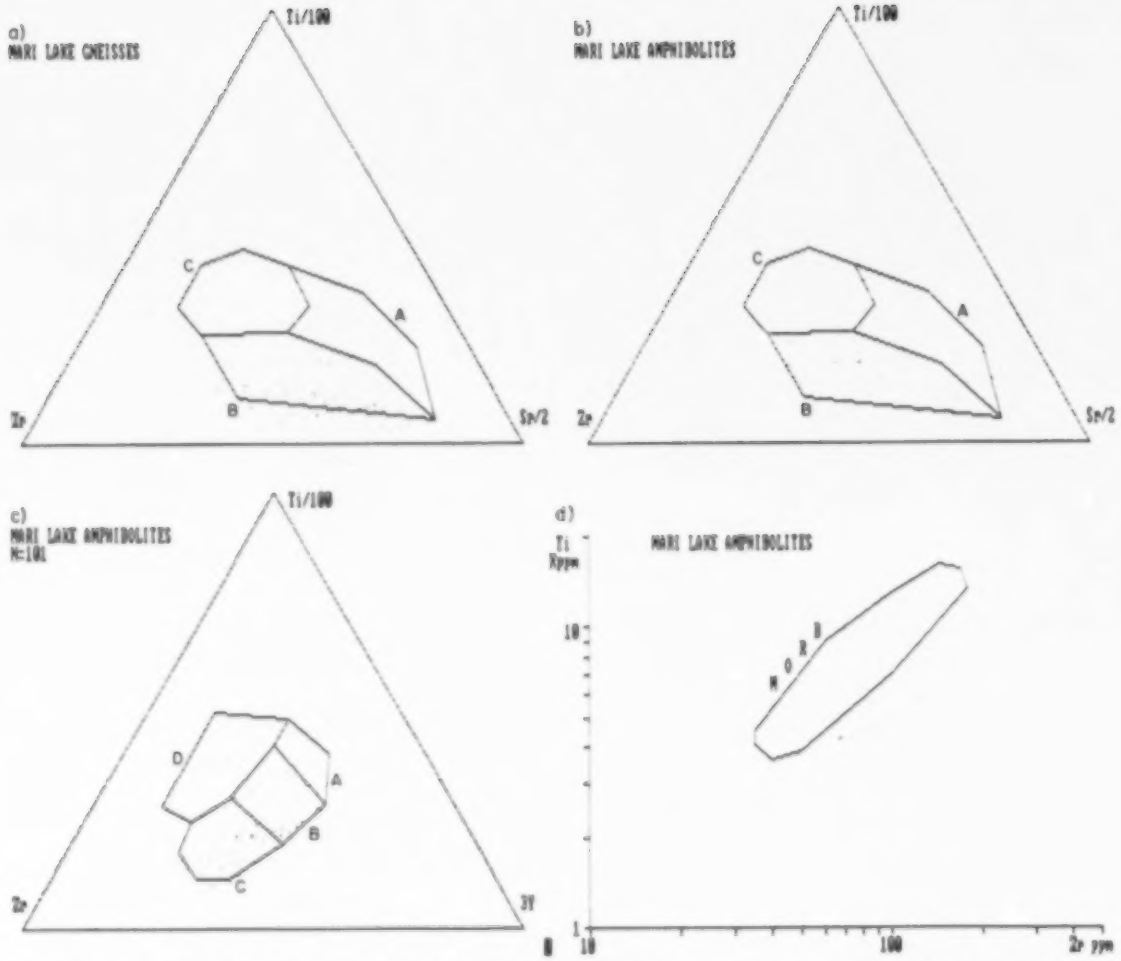


Figure 2 - Selected discriminant element plots illustrating chemical heterogeneity in the sample populations. a) Zr-Ti/100-3Y plot for Mari Lake gnesses; A, low potassium tholeiites; B, ocean floor basalts; C, calc-alkali basalts; D, within-plate basalts. b) Zr-Ti/100-Sr/2 plot for Mari Lake amphibolites; A, low potassium tholeiites; B, calc-alkali basalts; C, ocean floor basalts. c) Zr-Ti/100-3Y plot for Mari Lake amphibolites; fields as in (a). d) log Ti-log Zr plot for Mari Lake amphibolites; MORB, mid-ocean ridge basalts.

## The 1986 Program

This year's work concentrated on detailed sampling of an area near known anomalous base and precious metals in the Kisseynew Domain at the north end of Wildnest Lake and over economic and barren zones in a future gold production area, the La Ronge belt. The objective of the field study was to test the efficacy (in terms of feasibility and cost) of lithogeochemical surveys in the delineation of mineralized areas. Since no economic concentrations of gold are presently known in the Kisseynew Domain, it was necessary to include detailed sampling of the 'Rod' zone and two barren areas in the La Ronge Belt. In addition, results from the 1986 survey and those of 1985 were combined to further evaluate the 'metallotect' concept.

### Wildnest Lake Area

The area, shown in Fig. 3, was selected for two reasons, the first being its proximity to copper and gold mineralization encountered on the east side of Manson Bay, and secondly because the lakeshore section allowed detailed sampling across the generally north- to northeast-trending major foliation. Mature forest precluded any attempt to run detailed sampling traverses inland.

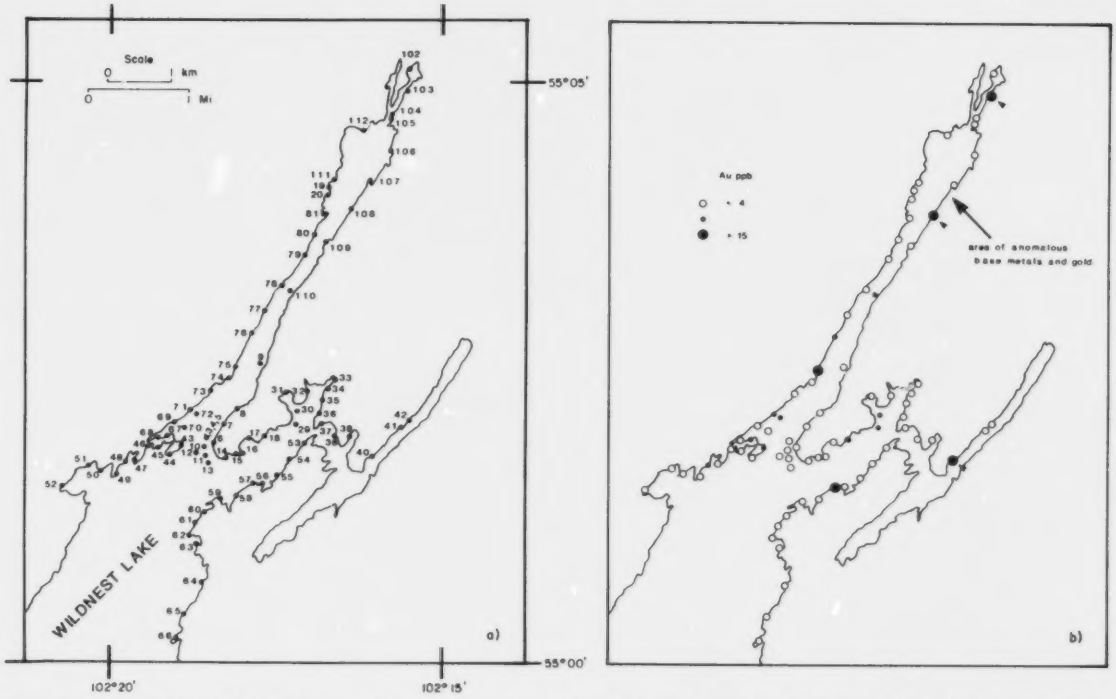


Figure 3 - 1986 Wildnest Lake survey: a) sample locations; b) Au values (arrowhead indicates a Au value greater than 100 ppb).

Where possible, samples were collected every 100 m across strike. Two other areas to the north, Keep and Stump Lakes (Figs. 4 and 5) were also sampled under the program.

Rocks in the southern part of the Wildnest Lake area are predominantly calc-silicates with some felsic gneisses (commonly graphitic and suggestive of a greywacke protolith) and amphibolites (tentatively assigned a volcanic protolith). As one moves north the rocks become more gneissic and in the Keep Lake area calc-silicates are virtually absent. Typically, primary fabrics are absent; however, occasional deformed plagioclase phenocrysts have been identified in areas of amphibolitic material (e.g., locality 57, Fig. 3a).

This rock texture has been encountered in various localities and is suggestive of a persistent feldspar-phyric igneous rock associated with the 'metallotect'. At the DOLLY showing on Mari Lake feldspar-phyric amphibolite contains anomalous gold, as does a similar unit on Melgurd Lake.

Geochemical data on the samples have just been received; however, some preliminary conclusions can be drawn:

1) the summary statistics (Table 4) illustrate that the rocks are similar to those of the 1985 survey (Table 1) except that the CaO and LOI averages are higher due to the prevalence of calc-silicate rocks;
2) the mean gold value and standard deviation are higher than those of the regional survey, suggesting that the presence of mineralization in Manson Bay is reflected on the much larger scale of this survey;
3) copper values are not, on average, noticeably enriched;
4) high gold values (Fig. 3b) are scattered through much of the survey area (values over 100 ppb are indicated with an arrowhead) and do not pinpoint the area of known mineralization;
5) the highest gold value occurs at locality 40 (Fig. 3a) in a magnetite-quartz rock (iron formation?); this value of 6400 ppb has been excluded from all statistical calculations because of its possible 'outlier effect' on the results;
6) of particular interest is the observation that the feldspar-phyric amphibolite at locality 57 (Fig. 3a) has a gold value of 63 ppb, further indicating that the feldspar-phyric units act as hosts to (syngenetic?) gold concentrations.

The 1985 data from Mari Lake indicate that there is a positive correlation between gold and copper values (cf. Table 5 (Cu above mean plus one standard deviation) and Table 6 (Au above mean plus one standard deviation) with Table 1 (Cu and Au mean values)).

Table 4 - Summary Statistics of 1986 Wildnest Lake Data (112 Samples).

| | MEAN | S.D. | MIN | MAX | GMEAN | GM-S.D. | GM+S.D. | LOGMEAN | LOG S.D. |
|---|---|---|---|---|---|---|---|---|---|
| SiO2 | 61.11 | 9.74 | 42.50 | 91.13 | 60.34 | 51.36 | 70.89 | 4.1000 | 0.1611 |
| TiO2 | 0.57 | 0.41 | 0.03 | 2.43 | 0.45 | 0.22 | 0.92 | -0.7916 | 0.7003 |
| Al2O3 | 15.12 | 3.90 | 1.74 | 23.52 | 14.36 | 9.80 | 20.80 | 2.6644 | 0.3743 |
| Fe2O3 | 0.74 | 0.46 | 0.03 | 2.53 | 0.58 | 0.26 | 1.30 | -0.5410 | 0.8057 |
| MnO | 0.20 | 0.50 | 0.01 | 3.73 | 0.10 | 0.03 | 0.29 | -2.3090 | 1.0547 |
| FeO | 6.01 | 3.70 | 0.27 | 20.44 | 4.73 | 2.13 | 10.50 | 1.5539 | 0.7978 |
| MgO | 3.19 | 3.01 | 0.16 | 20.23 | 2.33 | 1.04 | 5.21 | 0.8473 | 0.8037 |
| CaO | 7.81 | 5.97 | 0.24 | 33.50 | 5.79 | 2.50 | 13.40 | 1.7560 | 0.8395 |
| Na2O | 2.93 | 1.48 | 0.01 | 6.87 | 2.24 | 0.75 | 6.67 | 0.8070 | 1.0904 |
| K2O | 2.16 | 2.39 | 0.01 | 15.56 | 1.27 | 0.36 | 4.49 | 0.2400 | 1.2609 |
| P2O5 | 0.17 | 0.12 | 0.01 | 1.05 | 0.14 | 0.07 | 0.26 | -1.9949 | 0.6615 |
| H2O- | 0.07 | 0.04 | 0.01 | 0.24 | 0.06 | 0.03 | 0.13 | -2.8224 | 0.7629 |
| LOI | 1.86 | 1.97 | 0.01 | 14.40 | 1.30 | 0.53 | 3.20 | 0.2626 | 0.8991 |
| Ba | 300.45 | 303.37 | 1.00 | 1886.00 | 122.92 | 17.81 | 848.55 | 4.8115 | 1.9320 |
| Cr | 113.99 | 576.99 | 1.00 | 5730.00 | 10.53 | 1.69 | 65.83 | 2.3546 | 1.8324 |
| Cu | 56.30 | 92.05 | 1.00 | 486.00 | 20.16 | 4.20 | 96.86 | 3.0039 | 1.5694 |
| Nb | 7.45 | 3.75 | 2.60 | 20.70 | 6.65 | 4.12 | 10.72 | 1.8942 | 0.4783 |
| Ni | 28.32 | 81.55 | 1.00 | 751.00 | 9.13 | 2.45 | 33.96 | 2.2113 | 1.3138 |
| Pb | 8.85 | 16.87 | 1.00 | 176.00 | 6.25 | 3.18 | 12.28 | 1.8328 | 0.6754 |
| Rb | 26.96 | 25.80 | 1.00 | 165.00 | 16.21 | 5.26 | 49.94 | 2.7856 | 1.1253 |
| Sr | 282.89 | 278.50 | 1.00 | 1539.00 | 186.97 | 65.14 | 536.67 | 5.2309 | 1.0544 |
| Th | 2.59 | 1.90 | 1.00 | 10.00 | 2.11 | 1.13 | 3.93 | 0.7446 | 0.6250 |
| U | 2.63 | 1.33 | 1.00 | 9.00 | 2.33 | 1.41 | 3.84 | 0.8453 | 0.5003 |
| V | 138.11 | 153.13 | 1.00 | 1132.00 | 66.91 | 15.51 | 288.61 | 4.2033 | 1.4617 |
| Y | 22.24 | 13.60 | 1.00 | 68.00 | 17.97 | 8.72 | 37.03 | 2.8884 | 0.7232 |
| Zn | 90.41 | 48.16 | 19.00 | 381.00 | 81.36 | 51.70 | 128.05 | 4.3989 | 0.4535 |
| Zr | 73.14 | 48.61 | 9.00 | 232.00 | 58.47 | 29.19 | 117.12 | 4.0685 | 0.6947 |
| Au | 6.65 | 27.18 | 0.10 | 243.00 | 1.25 | 0.28 | 5.59 | 0.2236 | 1.4967 |

In the Wildnest Lake area however, although the copper and gold distributions (Table 4) are similar in terms of the regional survey, the highest gold values (greater than 35 ppb, Table 8) show no relationship to high copper values. This is taken as evidence that the strongest enrichments of gold are not a result of the same process(es) that formed the copper enrichments. The Keep Lake gold data (Fig. 4b) show little evidence of a continuation of the Manson Bay mineralization, some 7 km along strike to the south. The Stump Lake data (Fig. 5b), are interesting in that enhanced gold values occur in typical 'metallotect' rocks some 25 km north and west of the Manson Bay mineralization. The data tables illustrate that the average gold value in the Kisseynew Domain rocks is about 3 ppb; thus, it is suggested that a cheaper analytical technique with a detection limit of 1 to 5 ppb, rather than the 0.1 ppb limit adopted for this research, is adequate for exploration programs in the area.

Based upon the limited interpretation to date, it would apear that the areas of enriched copper values are also enriched in gold and are probably a manifestation of syngenetic concentrations of these elements in the 'metallotect'. On the other hand, the highest gold concentrations are not correlative with highest copper values and are perhaps manifestations of some tectonically controlled secondary epigenetic process.

La Ronge Belt

Detailed smpling of the ROD zone (Fig. 6) and two supposedly similar barren zones, on Gibbons Lake and Perepelitz Lake (Fig. 7), was undertaken to assess the geochemical response over such zones. The samples, taken where possible every 3 m, have been submitted for a multi-element analytical package of 52 elements. At the time this report was written, no results had been received.

## Conclusions

The basic and obvious deduction from the Kisseynew study is, to paraphrase an adage, that "gold is where you assay for it". Other than through detailed sampling and gold assaying, the results so far have failed to establish any clear lithogeochemical exploration technique for delineating areas of gold potential within the Kisseynew 'metallotect'. The data obviously illustrate that the 'metallotect' has gold potential, but further work is required to find a successful methoed (geochemical, stratigraphic, structural or

Table 5 - Summary Statistics of 1985 Mari Lake Samples High in Copper (19 Samples, greater than 120 ppm).

| | MEAN | S.D. | MIN | MAX | GMEAN | GM-S.D. | GM+S.D. | LOGMEAN | LOG S.D. |
|---|---|---|---|---|---|---|---|---|---|
| SiO2 | 52.43 | 3.56 | 45.98 | 60.56 | 52.32 | 48.91 | 55.96 | 3.9573 | 0.0673 |
| TiO2 | 1.04 | 0.53 | 0.49 | 2.48 | 0.94 | 0.59 | 1.49 | -0.0664 | 0.4678 |
| Al2O3 | 17.23 | 2.70 | 11.30 | 21.71 | 17.02 | 14.44 | 20.07 | 2.8345 | 0.1649 |
| Fe2O3 | 1.11 | 0.30 | 0.70 | 2.00 | 1.00 | 0.84 | 1.38 | 0.0747 | 0.2481 |
| MnO | 0.16 | 0.05 | 0.09 | 0.29 | 0.15 | 0.11 | 0.20 | -1.8860 | 0.2858 |
| FeO | 9.01 | 2.46 | 5.64 | 16.83 | 8.73 | 6.82 | 11.19 | 2.1672 | 0.2480 |
| MgO | 5.36 | 1.98 | 2.87 | 10.87 | 5.07 | 3.63 | 7.08 | 1.6234 | 0.3338 |
| CaO | 10.29 | 1.91 | 7.13 | 13.35 | 10.12 | 8.34 | 12.28 | 2.3141 | 0.1935 |
| Na2O | 2.39 | 0.82 | 0.95 | 3.58 | 2.23 | 1.51 | 3.31 | 0.8035 | 0.3930 |
| K2O | 0.71 | 0.41 | 0.13 | 1.78 | 0.59 | 0.30 | 1.16 | -0.5234 | 0.6719 |
| P2O5 | 0.27 | 0.11 | 0.17 | 0.60 | 0.25 | 0.18 | 0.36 | -1.3796 | 0.3564 |
| H2O- | 0.04 | 0.03 | 0.01 | 0.08 | 0.03 | 0.02 | 0.07 | -3.4251 | 0.7210 |
| LOI | 0.89 | 0.65 | 0.01 | 2.54 | 0.60 | 0.18 | 2.01 | -0.5055 | 1.2050 |
| Ba | 130.53 | 215.53 | 1.00 | 991.00 | 38.14 | 4.30 | 338.00 | 3.6413 | 2.1820 |
| Cr | 227.84 | 554.93 | 6.00 | 2496.00 | 79.38 | 20.21 | 311.74 | 4.3742 | 1.3680 |
| Cu | 233.37 | 193.88 | 125.00 | 1013.00 | 202.39 | 128.66 | 318.38 | 5.3102 | 0.4530 |
| Nb | 6.98 | 3.78 | 2.60 | 14.10 | 6.04 | 3.44 | 10.58 | 1.7981 | 0.5613 |
| Ni | 106.58 | 157.00 | 12.00 | 722.00 | 65.36 | 25.82 | 165.45 | 4.1798 | 0.9288 |
| Pb | 7.68 | 7.10 | 2.00 | 32.00 | 5.99 | 3.06 | 11.71 | 1.7901 | 0.6705 |
| Rb | 8.68 | 8.37 | 1.00 | 28.00 | 5.37 | 1.83 | 15.77 | 1.6811 | 1.0769 |
| Sr | 259.26 | 153.48 | 40.00 | 778.00 | 222.81 | 122.62 | 404.84 | 5.4063 | 0.5972 |
| Th | 2.26 | 1.79 | 1.00 | 8.00 | 1.80 | 0.93 | 3.49 | 0.5899 | 0.6589 |
| U | 1.58 | 0.77 | 1.00 | 3.00 | 1.43 | 0.91 | 2.23 | 0.3559 | 0.4483 |
| V | 273.84 | 151.74 | 151.00 | 818.00 | 248.60 | 163.87 | 377.12 | 5.5158 | 0.4167 |
| Y | 26.47 | 10.87 | 11.00 | 55.00 | 24.58 | 16.56 | 36.49 | 3.2019 | 0.3951 |
| Zn | 73.74 | 31.67 | 22.00 | 143.00 | 66.99 | 41.91 | 107.06 | 4.2045 | 0.4689 |
| Zr | 96.58 | 60.48 | 20.00 | 239.00 | 79.87 | 41.46 | 153.88 | 4.3804 | 0.6557 |
| Au | 23.52 | 50.32 | 0.20 | 222.00 | 5.56 | 0.85 | 36.50 | 1.7153 | 1.8821 |

otherwise) that will reduce the size of target areas within the 'metallotect'.

## Acknowledgements

I am most grateful to Ted Baumgartner, Hudson Bay Exploration and Development, for permission to mention the Manson Bay mineralization. Also many thanks to my friend and colleague John Pearson for sharing camp with an old timer with back problems. Greg Vogelsang was a dedicated and conscientious junior and John Siryj was, as usual, one of the most stimulating people I encountered in Flin Flon.

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Table 6 - Summary Statistics of 1985 Mari Lake Samples High in Gold (7 Samples, greater than 20 ppm).

| | MEAN | S.D. | MIN | MAX | GMEAN | GM-S.D. | GM+S.D. | LOGMEAN | LOG S.D. |
|---|---|---|---|---|---|---|---|---|---|
| SiO2 | 49.46 | 2.76 | 45.41 | 52.39 | 49.39 | 46.66 | 52.28 | 3.8997 | 0.0569 |
| TiO2 | 0.98 | 0.46 | 0.62 | 1.64 | 0.90 | 0.57 | 1.40 | -0.1088 | 0.4453 |
| Al2O3 | 19.96 | 1.71 | 18.09 | 21.75 | 19.90 | 18.25 | 21.70 | 2.9907 | 0.0867 |
| Fe2O3 | 0.97 | 0.16 | 0.77 | 1.20 | 0.96 | 0.81 | 1.14 | -0.0428 | 0.1706 |
| MnO | 0.13 | 0.02 | 0.11 | 0.15 | 0.13 | 0.11 | 0.15 | -2.0479 | 0.1343 |
| FeO | 7.86 | 1.31 | 6.27 | 9.70 | 7.77 | 6.56 | 9.19 | 2.0499 | 0.1685 |
| MgO | 4.59 | 0.96 | 3.94 | 6.69 | 4.52 | 3.76 | 5.43 | 1.5088 | 0.1832 |
| CaO | 11.46 | 1.03 | 10.46 | 13.19 | 11.42 | 10.46 | 12.48 | 2.4355 | 0.0883 |
| Na2O | 2.34 | 0.77 | 0.95 | 3.03 | 2.19 | 1.43 | 3.35 | 0.7834 | 0.4248 |
| K2O | 1.15 | 1.40 | 0.26 | 4.30 | 0.78 | 0.34 | 1.82 | -0.2425 | 0.8432 |
| P2O5 | 0.27 | 0.16 | 0.17 | 0.60 | 0.24 | 0.15 | 0.38 | -1.4378 | 0.4726 |
| H2O- | 0.03 | 0.02 | 0.01 | 0.06 | 0.02 | 0.01 | 0.05 | -3.7643 | 0.7094 |
| LOI | 1.03 | 0.91 | 0.35 | 3.01 | 0.81 | 0.41 | 1.63 | -0.2058 | 0.6923 |
| Ba | 158.29 | 183.61 | 3.00 | 561.00 | 79.92 | 16.09 | 396.83 | 4.3810 | 1.6825 |
| Cr | 108.71 | 53.73 | 12.00 | 145.00 | 85.28 | 33.32 | 218.27 | 4.4460 | 0.9398 |
| Cu | 278.29 | 329.69 | 7.00 | 1001.00 | 144.80 | 32.19 | 651.28 | 4.9753 | 1.5036 |
| Nb | 7.23 | 3.67 | 3.00 | 14.00 | 6.49 | 3.93 | 10.73 | 1.8709 | 0.5023 |
| Ni | 66.29 | 27.14 | 35.00 | 121.00 | 62.22 | 42.71 | 90.65 | 4.1307 | 0.3763 |
| Pb | 15.57 | 13.78 | 3.00 | 36.00 | 10.59 | 4.00 | 28.03 | 2.3598 | 0.9733 |
| Rb | 20.43 | 37.58 | 1.00 | 104.00 | 5.65 | 1.02 | 31.22 | 1.7311 | 1.7100 |
| Sr | 280.71 | 51.58 | 212.00 | 364.00 | 276.72 | 230.50 | 332.20 | 5.6230 | 0.1827 |
| Th | 1.43 | 0.53 | 1.00 | 2.00 | 1.35 | 0.93 | 1.95 | 0.2971 | 0.3705 |
| U | 1.43 | 0.53 | 1.00 | 2.00 | 1.35 | 0.93 | 1.95 | 0.2971 | 0.3705 |
| V | 210.43 | 77.56 | 152.00 | 356.00 | 200.23 | 144.40 | 277.64 | 5.2995 | 0.3269 |
| Y | 24.29 | 10.19 | 11.00 | 42.00 | 22.50 | 14.65 | 34.55 | 3.1134 | 0.4289 |
| Zn | 68.86 | 30.86 | 39.00 | 128.00 | 63.64 | 41.72 | 97.09 | 4.1533 | 0.4224 |
| Zr | 79.71 | 48.41 | 20.00 | 178.00 | 67.78 | 35.43 | 129.66 | 4.2163 | 0.6486 |
| Au | 65.57 | 70.54 | 23.00 | 220.00 | 46.93 | 21.12 | 104.31 | 3.8487 | 0.7986 |

Table 7 - Summary Statistics of 1986 Wildnest Lake Samples High in Gold (5 Samples, greater than 20 ppb), 7 Samples. Based on Regional (Mari Lake) Data.

| | MEAN | S.D. | MIN | MAX | GMEAN | GM-S.D. | GM+S.D. | LOGMEAN | LOG S.D. |
|---|---|---|---|---|---|---|---|---|---|
| SiO2 | 55.45 | 10.45 | 45.38 | 68.85 | 54.69 | 45.45 | 65.80 | 4.0016 | 0.1849 |
| TiO2 | 1.07 | 0.69 | 0.60 | 2.23 | 0.93 | 0.53 | 1.63 | -0.0700 | 0.5576 |
| Al2O3 | 13.62 | 2.69 | 10.16 | 16.45 | 13.40 | 10.93 | 16.42 | 2.5950 | 0.2037 |
| Fe2O3 | 1.06 | 0.32 | 0.65 | 1.45 | 1.02 | 0.74 | 1.39 | 0.0159 | 0.3159 |
| MnO | 0.24 | 0.14 | 0.14 | 0.48 | 0.21 | 0.13 | 0.35 | -1.5544 | 0.4932 |
| FeO | 8.56 | 2.56 | 5.27 | 11.68 | 8.24 | 6.03 | 11.28 | 2.1096 | 0.3137 |
| MgO | 8.23 | 7.12 | 1.17 | 20.23 | 5.82 | 2.09 | 16.20 | 1.7621 | 1.0232 |
| CaO | 8.74 | 7.13 | 2.36 | 19.97 | 6.52 | 2.69 | 15.77 | 1.8746 | 0.8835 |
| Na2O | 1.66 | 1.21 | 0.45 | 3.30 | 1.26 | 0.52 | 3.06 | 0.2279 | 0.8889 |
| K2O | 1.21 | 1.41 | 0.07 | 3.22 | 0.53 | 0.11 | 2.59 | -0.6431 | 1.5938 |
| P2O5 | 0.18 | 0.09 | 0.09 | 0.31 | 0.16 | 0.10 | 0.27 | -1.8221 | 0.5189 |
| H2O- | 0.09 | 0.02 | 0.06 | 0.12 | 0.09 | 0.06 | 0.11 | -2.4607 | 0.2773 |
| LOI | 1.75 | 0.77 | 0.82 | 2.90 | 1.61 | 1.01 | 2.55 | 0.4760 | 0.4616 |
| Ba | 58.40 | 89.15 | 1.00 | 284.00 | 7.04 | 0.48 | 103.87 | 1.9522 | 2.6910 |
| Cr | 464.80 | 762.35 | 3.00 | 1799.00 | 64.05 | 3.80 | 1080.19 | 4.1596 | 2.8253 |
| Cu | 101.00 | 131.51 | 16.00 | 333.00 | 57.40 | 18.39 | 179.14 | 4.0501 | 1.1381 |
| Nb | 10.60 | 6.07 | 5.60 | 20.70 | 9.53 | 5.68 | 16.00 | 2.2546 | 0.5179 |
| Ni | 189.40 | 318.22 | 3.00 | 751.00 | 36.98 | 3.52 | 388.35 | 3.6103 | 2.3516 |
| Pb | 39.60 | 76.26 | 4.00 | 176.00 | 10.81 | 2.24 | 52.15 | 2.3808 | 1.5734 |
| Rb | 18.20 | 18.17 | 4.00 | 48.00 | 11.00 | 3.47 | 34.88 | 2.3982 | 1.1536 |
| Sr | 194.00 | 171.16 | 57.00 | 485.00 | 147.08 | 65.06 | 332.50 | 4.9910 | 0.8157 |
| Th | 1.40 | 0.55 | 1.00 | 2.00 | 1.32 | 0.90 | 1.93 | 0.2773 | 0.3797 |
| U | 3.20 | 0.84 | 2.00 | 4.00 | 3.10 | 2.33 | 4.13 | 1.1326 | 0.2847 |
| V | 178.20 | 164.55 | 8.00 | 353.00 | 69.66 | 10.00 | 481.66 | 4.2437 | 1.9336 |
| Y | 34.80 | 17.27 | 23.00 | 65.00 | 32.20 | 21.30 | 48.69 | 3.4721 | 0.4135 |
| Zn | 156.60 | 130.60 | 53.00 | 381.00 | 124.02 | 59.44 | 258.78 | 4.8204 | 0.7355 |
| Zr | 83.20 | 39.67 | 36.00 | 141.00 | 75.36 | 45.12 | 125.85 | 4.3222 | 0.5128 |
| Au | 105.36 | 86.06 | 31.90 | 243.00 | 81.48 | 36.73 | 180.78 | 4.4004 | 0.7969 |

Table 8 - Summary Statistics of 1986 Wildnest Lake Samples High in Gold (4 Samples, greater than 35 ppb).

| | MEAN | S.D. | MIN | MAX | GMEAN | GM-S.D. | GM+S.D. | LOGMEAN | LOG S.D. |
|---|---|---|---|---|---|---|---|---|---|
| SiO2 | 57.97 | 10.17 | 49.02 | 68.05 | 57.30 | 48.03 | 68.35 | 4.0482 | 0.1764 |
| TiO2 | 0.78 | 0.27 | 0.60 | 1.18 | 0.75 | 0.55 | 1.02 | -0.2880 | 0.3126 |
| Al2O3 | 14.48 | 2.16 | 11.87 | 16.45 | 14.36 | 12.32 | 16.73 | 2.6641 | 0.1533 |
| Fe2O3 | 0.96 | 0.27 | 0.65 | 1.38 | 0.93 | 0.70 | 1.23 | -0.0731 | 0.2834 |
| MnO | 0.26 | 0.15 | 0.14 | 0.48 | 0.23 | 0.14 | 0.39 | -1.4687 | 0.5248 |
| FeO | 7.79 | 2.16 | 5.27 | 10.55 | 7.56 | 5.69 | 10.04 | 2.0225 | 0.2839 |
| MgO | 5.23 | 2.75 | 1.17 | 7.03 | 4.27 | 1.79 | 10.14 | 1.4509 | 0.8660 |
| CaO | 8.97 | 8.21 | 2.36 | 19.97 | 6.23 | 2.26 | 17.18 | 1.8301 | 1.0137 |
| Na2O | 1.94 | 1.19 | 0.45 | 3.30 | 1.55 | 0.65 | 3.70 | 0.4389 | 0.8698 |
| K2O | 1.49 | 1.45 | 0.23 | 3.22 | 0.97 | 0.24 | 3.20 | -0.1391 | 1.3012 |
| P2O5 | 0.15 | 0.07 | 0.09 | 0.24 | 0.14 | 0.09 | 0.21 | -1.9849 | 0.4271 |
| H2O- | 0.09 | 0.02 | 0.06 | 0.12 | 0.09 | 0.07 | 0.12 | -2.4111 | 0.2934 |
| LOI | 1.79 | 0.88 | 0.82 | 2.90 | 1.62 | 0.95 | 2.76 | 0.4807 | 0.5328 |
| Ba | 72.75 | 96.84 | 1.00 | 204.00 | 11.48 | 0.67 | 196.46 | 2.4402 | 2.8403 |
| Cr | 131.25 | 182.21 | 3.00 | 390.00 | 27.82 | 2.40 | 322.73 | 3.3258 | 2.4510 |
| Cu | 43.00 | 25.15 | 16.00 | 74.00 | 36.99 | 19.07 | 71.76 | 3.6106 | 0.6627 |
| Nb | 8.18 | 2.70 | 5.60 | 11.60 | 7.85 | 5.66 | 10.89 | 2.0607 | 0.3270 |
| Ni | 49.00 | 60.81 | 3.00 | 130.00 | 17.42 | 2.62 | 116.01 | 2.8575 | 1.8962 |
| Pb | 48.00 | 65.34 | 4.00 | 176.00 | 12.53 | 2.12 | 74.04 | 2.5280 | 1.7766 |
| Rb | 21.75 | 18.87 | 4.00 | 48.00 | 14.17 | 4.44 | 45.25 | 2.6512 | 1.1609 |
| Sr | 228.25 | 176.75 | 89.00 | 485.00 | 186.41 | 91.10 | 381.44 | 5.2280 | 0.7160 |
| Th | 1.50 | 0.58 | 1.00 | 2.00 | 1.41 | 0.95 | 2.11 | 0.3466 | 0.4002 |
| U | 3.25 | 0.96 | 2.00 | 4.00 | 3.13 | 2.25 | 4.35 | 1.1411 | 0.3260 |
| V | 134.50 | 152.88 | 8.00 | 318.00 | 46.43 | 6.46 | 333.51 | 3.8380 | 1.9717 |
| Y | 37.00 | 19.11 | 23.00 | 65.00 | 33.97 | 21.51 | 53.66 | 3.5256 | 0.4571 |
| Zn | 173.50 | 144.35 | 53.00 | 381.00 | 134.74 | 59.23 | 306.51 | 4.9034 | 0.8219 |
| Zr | 68.75 | 26.58 | 36.00 | 99.00 | 64.43 | 41.81 | 99.30 | 4.1656 | 0.4326 |
| Au | 123.73 | 87.33 | 54.60 | 243.80 | 103.01 | 51.51 | 205.99 | 4.6349 | 0.6930 |

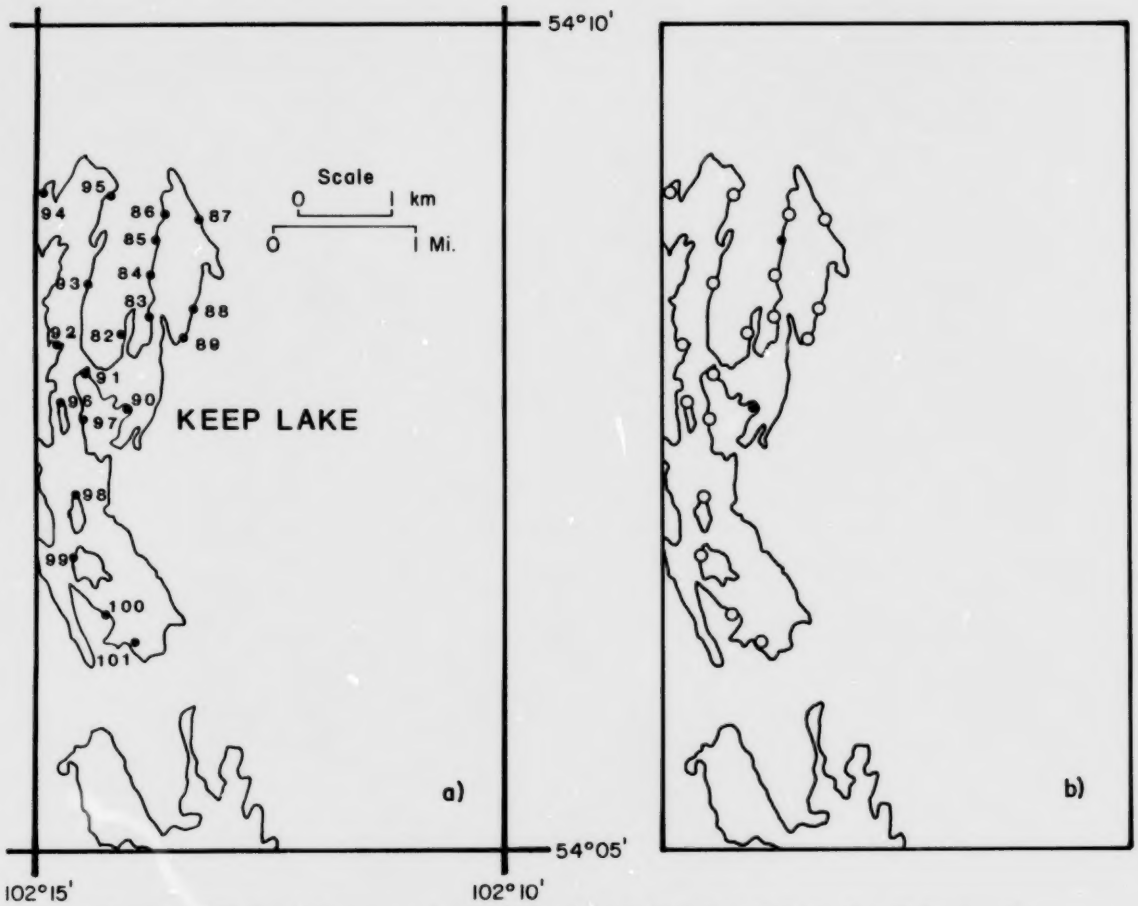


Figure 4 - 1986 Keep Lake survey: A, sample locations; B, Au values (Refer to Fig. 3B for legend).

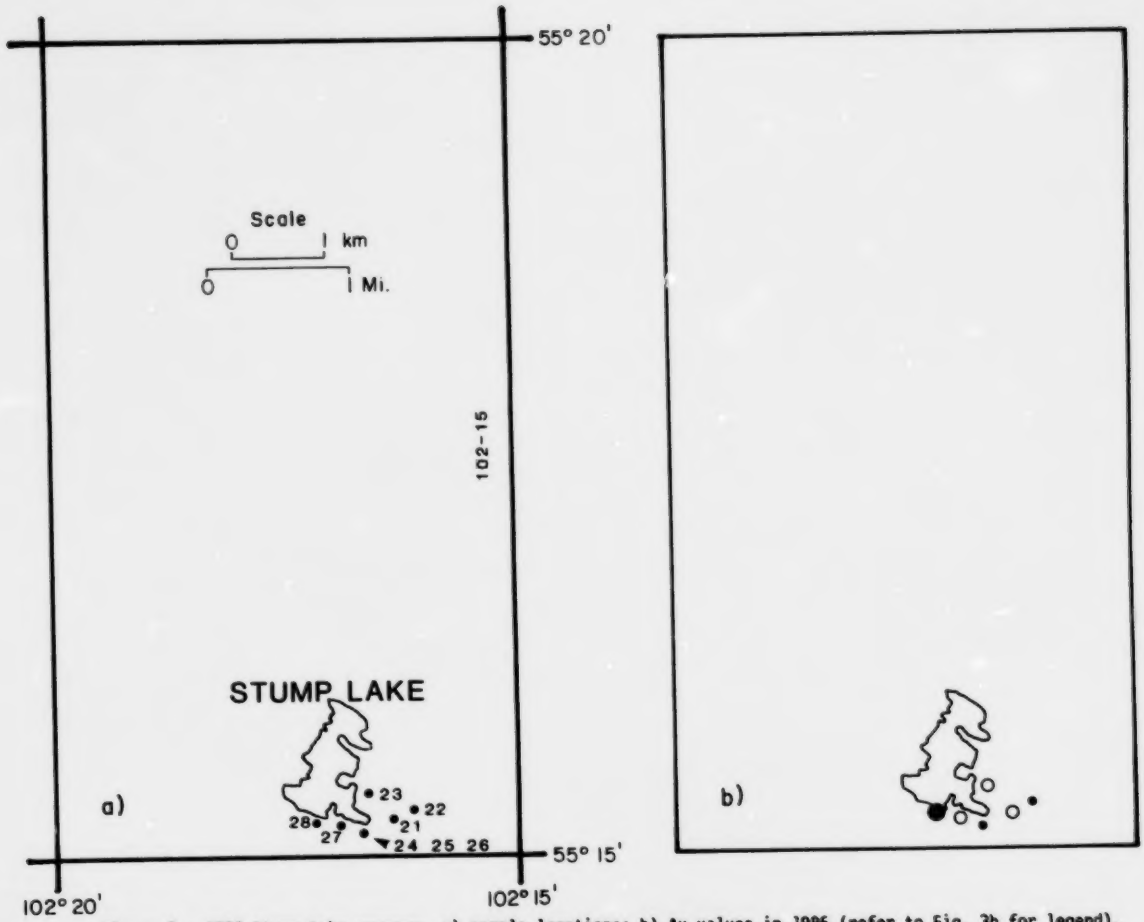


Figure 5 - 1986 Stump Lake survey: a) sample locations; b) Au values in 1986 (refer to Fig. 3b for legend).

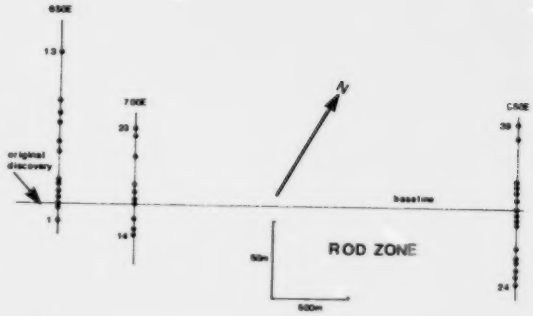


Figure 6 - Sample locations, ROD zone, near Star Lake in the La Ronge volcanic belt.

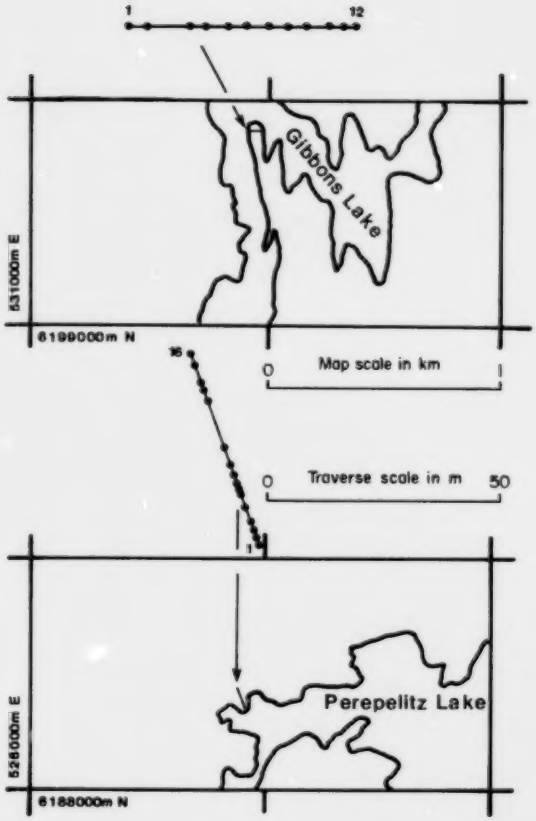


Figure 7 - Sample locations, 'barren' zones on Gibbons and Perepelitz Lakes in the La Ronge volcanic belt.

Project 8625

# Neodymium, Strontium and Lead Isotope Geochemistry Project

by Kenneth D. Collerson[1]

Collerson, K.D. (1986): Neodymium, strontium and lead isotope geochemistry project; in Summary of Investigations 1986, Saskatchewan Geological Survey; Saskatchewn Energy and Mines, Miscellaneous Report 86-4.

A unique feature of the end-early Proterozoic Trans-Hudson Orogen in Saskatchewan and Manitoba is that it is bounded by Archean cratons on both its southeastern and northwestern margins (Hoffman, 1984). These cratons are designated the Superior Craton and Churchill Craton by Lewry and Collerson (in prep.). Such a geologic configuration has provided important constraints on tectonic and petrological models for magmatic arc and suspect terrane accretion in the orogen (Lewry, 1981; Lewry et al., 1985, 1986, in press; Green et al., 1985a and b; Van Schmus et al., in press; Lewry and Collerson, in prep.) and affords an excellent opportunity to study the effects of orogenesis on older ensialic marginal terranes. Although the geological evolution of the Superior Craton is comparatively well known, relatively little is known about the Archean and Proterozoic history of the Churchill Craton. Previous reconnaissance Nd and Pb isotopic studies (Chauvel et al., in press; Todt et al., in prep.) in the Reindeer Zone of the Trans-Hudson Orogen indicate that crust formation involved mixing between depleted mantle-derived components, with short crustal residence times, and an earlier Archean component. Apart from an Nd isotopic analysis of the Saskatchewan Shield composite (McCulloch and Wasserburg, 1978), reconnaissance Rb-Sr isotopic data of Bell and Macdonald (1982), Bell and Blenkinsop (1982, 1983), Bell and Bikerman (1985) and preliminary Sr, Nd and U-Pb zircon age data of Collerson et al. (in prep.), chronology and isotopic evolution of the craton northwest of the Reindeer Zone is virtually unknown. Current field and isotopic data suggest that the Keewatin and Cree Lake Zones and the Peter Lake Domain may have had different Archean crustal evolutionary histories which have been variably "reworked" by metamorphism and anatexis during Hudsonian orogeny (Collerson et al., in prep.). In view of the role played by Archean crust in the geochemical evolution of suites in the Reindeer Zone, an understanding of the crustal evolution of the Churchill Craton is of importance to geodynamic models for the Trans-Hudson Orogen.

Sample collection was completed in September 1986 for a significantly expanded multi-system (Sr-Nd-Pb) isotopic study of rocks from the Reindeer and Cree Lake Zones and the Peter Lake Domain of the Thelon Segment of the Trans-Hudson Orogen in Saskatchewan. The study is being undertaken concurrently with U-Pb zircon geochronological studies at Kansas University by M. E. Bickford and W. R. Van Schmus (e.g., Van Schmus et al., this volume). Model age data, together with whole rock and mineral Sm-Nd, Rb-Sr and Pb-POb isochrons, will be determined for single specimens or critical suites of specimens with defined field relationships. The study will provide information about the time of crust-mantle separation, the effect of fractionation processes on isotopic systems, and scales of isotopic homogenization in different systems during partial melting and metamorphism associated with the Hudsonian and earlier thermotectonic events. Initial ratios determined from isochrons, or calculated for single samples using established zircon ages, will enable the isotopic composition of the contemporary mantle to be documented, thereby providing tighter age and compositional constraints on the evolution of depleted mantle sources. This data, combined with data for potential Archean end-member compositions in the Churchill Craton, will allow mixing models for the geochemical evolution of different suites within the orogen to be further refined.

Specific objectives of this study are as follows:

(1) To identify, define the distribution, and document the isotopic composition of Archean upper and lower crustal gneissic and granitic components in the Reindeer and Cree Lake Zones and the Peter Lake Domain, and to compare and contrast the Archean crustal history recorded within these different elements of the Churchill Craton.

(2) To document the regional distribution of tectonic, metamorphic and anatectic features associated with Hudsonian thermotectonism in the Churchill Craton and evaluate differences in scales of equilibration recorded by different isotopic systems. This aspect of the study will provide a regional data base on which crustal evolutionary models for the behaviour of the Churchill Craton during Hudsonian orogenesis can be based.

(3) To determine age limits for the Wollaston Group. This will be achieved by obtaining Nd

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Project funded under the Saskatchewan component of the Canada-Saskatchewan Subsidiary Agreement on Mineral Development 1984-89.

and U-Pb (zircon) isotopic data for felsic metavolcanics in the Wollaston Group. These data will be compared and contrasted with Nd data for higher grade metavolcanics in the central and western area of the Cree Lake Zone in an attempt to resolve whether they are correlatives (cf. Lewry et al., 1985).

(4) To determine the age and source composition of posttectonic layered gabbroic and dioritic plutons in the Peter Lake Domain using Nd isotopic data for minerals and whole rock suites. Well constrained data of this type are needed for quantitative models of Precambrian crust-mantle differentiation.

(5) To determine the age and source of posttectonic anorogenic granitic and syenitic bodies in the Peter lake Domain in order to provide information concerning the nature and age of deep continental crust within this domain.

Sample Descriptions

Samples collected during September 1986 are summarized below. Approximate specimen localities are given in brackets. Localities also sampled for U-Pb zircon dating by Bickford and Van Schmus are asterisked. The collection augments material sampled during 1985 (Collerson and Lewry, 1985).

**Wollaston Domain: Gneissic Inliers (Presumed Basement)**

HUD 86* (small island in northern part of Compulsion Bay): Aplitic granitic gneiss.

HUD 86-42* (small island in northern part of Compulsion Bay): Coarse-grained biotite-hornblende-bearing granitic gneiss. Both HUD 86-41 and HUD 86-42 exhibit simple anastomosing fabrics and contain boudins of amphibolite that are interpreted as metabasic dykes.

HUD 86-43 (southeastern shore of the inner part of Compulsion Bay): Coarse-grained hornblende-biotite-bearing tonalitic gneiss from an outcrop that contains discontinuous veinlets of aplitic material similar to HUD 86-41.

HUD 86-54* (western shore of Bailey Lake): Biotite-amphibole-bearing granitic (quartz monzonitic) augen gneiss. Gneisses from this locality, termed the Johnson River Granite, yielded a U-Pb zircon age of 2494 ± 38 Ma (Ray and Wanless, 1980).

**Wollaston Domain: Wollaston Group**

HUD 86-31 (north shore of Raven Lake): Wollaston Group amphibolite.

HUD 86-32 (north shore of Raven Lake): Wollaston Group felsic schist.

HUD 86-58* (small island southwest of Blue Island in Wollaston Lake): Fine-grained quartzofeldspathic inclusion in amphibolite. Possibly fragmental acid volcanic material enclosed in a fragmental basic to intermediate host. Inclusions are variable in distribution, ranging between 5 and 25 percent. They are very elongate and range in size from less than 0.5 by 5 cm to greater than 40 by 150 cm. The main fabric in the rock appears to be parallel to the axial planes of mesoscopic isoclinal folds. A second planar fabric cuts this at an oblique angle.

HUD 86-59 (small island southwest of Blue Island in Wollaston Lake): Edenite-anthophyllite-bearing amphibolite.

HUD 86-60 (small island southwest of Blue Island in Wollaston Lake): Specimen showing contact between amphibolite and felsic material.

HUD 86-61 (small island southwest of Blue Island in Wollaston Lke): Similar to HUD 86-60.

**Wollaston Domain: Post-Wollaston Group**

HUD 86-33 (north shore of Raven Lake): Posttectonic lamprophyre dyke cutting the Wollaston Group.

**Wollaston Domain/Peter Lake Domain Boundary Zone**

HUD 86-51 (small lake 3 km north of Sexsmith Lake): Meta-arkose from sequence of interlayered amphibolites, garnet-biotite schists, metapsammites and granitic gneisses. Sequence possibly represents early rift facies which was assembled along the southeastern margin of the Cree Lake Zone.

HUD 86-52* (small lake 3 km north of Sexsmith Lake): Medium- to fine-grained granitic gneiss with strong tectonite fabric.

HUD 86-53 (small lake 3 km north of Sexsmith Lake): Amphibolite with streaky discontinuous compositional layering that locally preserves rootless intrafolial folds. This is possibly an early rift-related volcanic rock in the Wollaston Group. Both the amphibolite and granitic gneiss exhibit much stronger tectonite fabrics than the meta-arkose.

**Peter Lake Domain**

HUD 86-34 (southern shore of Lyle Lake): Medium to fine generally massive posttectonic biotite-bearing syenogranite which appears to be cut by narrow localized shear zones.

HUD 86-35* (southern shore of Lyle Lake): Porphyritic microdioritic dyke cutting HUD 86-34. The dyke ranges in width up to 100 cm and displays a prominent chilled margin about 15 to 20 cm wide against the granite.

HUD 86-36 (southern shore of Lyle Lake): Ferrohastingsite-biotite-bearing syenogranite.

HUD 86-37* (southern shore of Lyle Lake): Ferrohastingsite-bearing syenogranite.

HUD 86-38 (north shore of lake 2.5 km east of Lyle Lake): Medium- to coarse-grained hornblende-biotite-bearing monzodiorite.

HUD 86-39 (southern shore of same lake): Similar granite to HUD 86-38. The unit appears to be designated on Map 199A (Lewry et al., 1980) as a basic component of the Peter Lake Complex.

HUD 86-40 (southern shore of same lake): Granitic gneiss which appears to be intruded by the Lyle Lake posttectonic granitic suite.

HUD 86-44* (lake 2 km east of Morwick Lake): Ettle Creek Granite. A massive, very coarse grained, apparently posttectonic hornblende-biotite-bearing A-type granite. This very coarse grained lithology is characterized by large euhedral grains of perthite up to 2 by 1 cm in size which have narrow rims of albite. These define a cumulus-like texture in which interstitial areas are occupied by smaller grains of quartz and ferromagnesian phases. Outcrops are cut by narrow mylonitic shear zones.

HUD 86-45 (lake 2 km east of Morwick Lake): Dioritic phase in the Ettle Creek Granite, occurring in diffuse patchy zones, 10 to 20 cm in width, in relatively massive outcrops of granite.

HUD 86-46 (lake 2 km east of Morwick Lake): Granite containing rare dioritic xenoliths.

HUD 86-47 (western shore of Patterson Island): Gabbroic phase of the Patterson Island Intrusion.

HUD 86-48 (western shore of Patterson Island): Monzodioritic phase of the Patterson Island Intrusion.

HUD 86-49 (western shore of Patterson Island): Xenolithic phase of HUD 86-48.

HUD 86-50 (western shore of Patterson Island): Porphyritic leucogabbro.

HUD 86-55 (southern shore of Taylor Lake): Hornblende pyroxenite believed to represent part of a differentiated basic intrusion.

HUD 86-56 (southern shore of Taylor Lake): Trondhjemitic agmatite leucosome which cuts the pyroxenite.

HUD 86-57 (southern shore of Taylor Lake): Sulphide-rich hornblende-bearing gabbro.

Outcrops in the Taylor Lake area of the Peter Lake Domain have very complex geological relationships. Units include a fragmented and agmatized basic intrusion which comprises hornblende pyroxenite (HUD 86-55) and hornblende-bearing gabbro (HUD 86-57). The agmatite leucosome (HUD 86-56) is trondhjemitic in composition. Cutting the agmatized basic unit are sheets of relatively homogeneous tonalitic gneiss with simple tectonite fabrics. Pyroxenite-gabbro exhibits sharp tectonic contacts with compositely layered tonalitic quartz dioritic gneiss which commonly contains boudins of fine-grained massive amphibolite interpreted as disrupted dykes. All of the above units are cut by a number of generations of aplite and pegmatite sheets. A "weakly foliated to massive hornblende-biotite, meta-quartz diorite" from this area yielded a U-Pb zircon age of 2538 ± 10 Ma (Ray and Wanless, 1980). From the previously described relationships it is clear that this unit is somewhat younger than the compositely layered tonalitic and quartz dioritic gneisses in the area.

HUD 86-62* (southwestern shore of Taylor Lake): Tonalitic gneiss.

HUD 86-63* (southwestern shore of Taylor Lake): Dioritic gneiss.

Both HUD 86-62 and HUD 86-63 occur as strongly deformed, relatively homogeneous sheets that appear to be tectonically intercalated with massive units of agmatitic gabbro and pyroxenite as well as with compositely layered units of finer grained amphibolite.

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Project 8607A

# U-Pb Zircon Geochronology Project for the Trans-Hudson Orogen: Current Sampling and Recent Results

by M.E. Bickford[1], W.R. Van Schmus[1], R. Macdonald, John F. Lewry[2] and J.G. Pearson

Bickford, M.E., Van Schmus, W.R., Macdonald, R., Lewry, J.F. and Pearson, J.G. (1986): U-Pb zircon geochronology project for the Trans-Hudson Orogen: current sampling and recent results; in Summary of Investigations 1986, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 86-4.

The program of analyzing zircons from rocks of the Trans-Hudson Orogen for precise age determination continued during the year at Kansas University. In the summer of 1986, samples were collected principally from the Flin Flon, Kisseynew and Hanson Lake Domains (M.E.M., J.F.L., R.M. and J.G.P.). This paper summarizes all results since the program started, reports preliminary details of new results, and documents the samples collected this summer. Full results of some of our previous work are given in Van Schmus et al. (in press).

All data presented here were obtained in the Isotope Geochemistry Laboratory at the University of Kansas by standard methods of mass spectrometry and isotope dilution analysis. Decay constants used are those of Steiger and Jaeger (1977). Uncertainties in ages were calculated by the methods of Ludwig (1980) and are given at the 1-sigma level. Some of the data presented are preliminary; analysis of more zircon fractions and the application of special techniques such as air abrasion (Krogh, 1982) and detailed hand-picking may change interpretation. The precise locations of samples collected for age determination are kept in the Saskatchewan Geological Survey Geochronological Database file.

Table 1 summarizes age data obtained since the project began in 1983, except for those reported in Van Schmus et al. (this volume) from the Nolan Block and the Uranium City area. Data obtained since our last report in the 1985 Summary of Investigations (Bickford and Van Schmus, 1985) are indicated in Table 1 with an asterisk (*). So far we have dated 41 samples in Saskatchewan, including the samples from the Nolan Block and Uranium City area.

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Field Support for this joint venture funded under the Saskatchewan component of the Canada-Saskatchewan Subsidiary Agreement on Mineral Development 1984-89.

Table 1 - Summary of Concordia Intercept Ages

| Sample No. | Unit | N | P | Model | Age (± 2σ) | L.I. |
|---|---|---|---|---|---|---|
| Trans-Hudson Orogen in Northern Saskatchewan | | | | | | |
| HUD83-1 | Metafelsite from Laroque Lake | 5 | <1 | 2 | 1876±33 | 203 |
| HUD83-3 | Tonalitic gneiss, Davin Lake Complex | 4 | 54 | 1 | 1863±12 | 786 |
| HUD83-5 | Brindson Lake Pluton | 4 | 30 | 2 | 1866±12 | 0 |
| HUD83-6 | Carroll Lake Gneiss | 4 | 1 | 2 | 1893±35 | 560 |
| HUD83-7 | Metarhyolite, Palf Lake | 3 | 93 | 1 | 1881±6 | 115 |
| HUD83-8 | Sahli Granite | (see text) | | | 1900/2500 | |
| HUD83-9 | Metarhyolite, Hanson Lake | 4 | 90 | 1 | 1888±12 | 460 |
| HUD83-11 | Tonalite, Deschambault Narrows | 4 | 96 | 1 | 1850±4 | 74 |
| HUD83-12 | Granodiorite, Wykes Lake Pluton | 5 | <1 | 4 | 1850±9 | 221 |
| HUD83-13 | Eyapaise Pluton | 5 | <1 | 4 | 1859±5 | 153 |
| HUD83-14 | Late pluton; intrudes HUD83-13 | 4 | 17 | 2 | 1836±7 | 97 |
| HUD83-16 | "Older gneiss" (= Eyahpaise Pluton?) | 6 | <1 | 2 | 1852±12 | 432 |

Table 1 - Summary of Concordia Intercept Ages (continued)

| Sample No. | Unit | N | P | Model | Age (± 2σ) | L.I. |
|---|---|---|---|---|---|---|
| HUD83-17 | Tonalitic gneiss, Davin Lake Complex | | | | | |
| | Unprocessed zircons (Group 1) | 5 | 21 | 2 | 1885±14 | 639 |
| | Air-abraded suite (Group 2) | 4 | .1 | 2 | 1922±24 | 733 |
| | Hand-picked coreless M(-3) | 1 | --- | 1 | 1867±8 | * |
| | *(assumed lower intercept of 700 Ma) | | | | | |
| HUD83-18 | Wathaman Batholith | 6 | <1 | 2 | 1852±14 | 450 |
| HUD83-20 | Macoun Lake Pluton | 4 | 77 | 1 | 1849±10 | 380 |
| HUD83-23 | Metarhyolite A, McLennan Lake | 4 | <1 | 2 | 1879±66 | 670 |
| HUD83-24 | Metarhyolite B, McLennan Lake | 10 | <1 | 4 | 1882±9 | 619 |
| | [less M(0), M(2)] | 8 | 14 | 2 | 1879±9 | 570 |
| HUD84-104 | Star Lake Pluton | 4 | <1 | 4 | 1848±14 | 441 |
| HUD84-133 | Metarhyolite, Upper Waddy Lake | 5 | 2 | 2 | 1880±7 | 35 |
| (*)HUD84-107 | Fork Lake Pluton | 5 | 11 | 2 | 1855±22 | 600 |
| (*)HUD84-108 | Nistoassini-Nayelles Pluton | 5 | <1 | 2 | 1853±10 | 200 |
| (*)HUD84-115 | Tonalite, Numabin Bay | 4 | 85 | 1 | 1837±8 | 602 |
| (*)HUD84-117 | Pegmatite, Nistoassini-Nayelles Pl. | 4 | <1 | 2 | 1859±11 | 7 |
| (*)HUD84-118 | Kenwood Lake Pluton | 4 | 29 | 2 | 1855±9 | 330 |
| (*)HUD84-134 | Upper Waddy Lake Stock | 3 | 55 | 1 | 1834±13 | 50 |
| (*)HUD84-139 | Contact Lake Pluton | 5 | <1 | 2 | 1853±16 | 449 |
| (*)HUD84-CL65 | Wathaman Batholith, Callin Lake | 5 | <1 | 2 | 1852±6 | 1 |
| (*)HUD84-ML07 | Wathaman Batholith, Mavis Lake | 5 | 83 | 1 | 1862±4 | 441 |
| (*)HUD84-RL11 | Wathaman Batholith, Reilly Lake | 8 | 84 | 1 | 1854±6 | 632 |
| (*)HUD84-WL03 | Wathaman batholith, Wathaman Lake | 4 | 63 | 1 | 1855±6 | 450 |
| (*)HUD84-ML08 | Wathaman Batholith, Mavis Lake | 4 | 77 | 1 | 1830±6 | 160 |
| Southern Saskatchewan Subsurface Samples | | | | | | |
| (*)SASK-2 | Tonalitic gneiss | 3 | 65 | 1 | 1862±4 | 42 |
| (*)SASK-8 | Granulitic gneiss | 2 | 49 | 1 | 1786±4 | 500 |
| (*)SASK-26 | Granodioritic gneiss | 4 | <.01 | 2 | 1914±50 | 574 |
| (*)SASK-34 | Post-tectonic granite | 3 | 24 | 1 | 1763±4 | 13 |
| (*)SASK-35 | Charnockitic gneiss | 6 | 40 | 1 | 2484±54 | 1410 |
| (*)SASK-48 | Megacrystic granite | 3 | <.01 | 2 | 1822±16 | 11 |
| 'Western Craton' Saskatchewan | | | | | | |
| (*)HUD85-1 | Junction Granite | 6 | approx. | | 1800 (older component) | |
| | | | approx. | | 1820 (young component) | |
| (*)HUD85-2 | Blue quartz gneiss | 2 | approx. | | 2290 (older component) | |
| | | | approx. | | 2000 (young component) | |
| (*)HUD85-8 | Gneissoid inclusion in anorthosite | 5 | complex | | 2000 (approximate) | |

Table 1 - Summary of Concordia Intercept Ages (continued)

| Sample No. | Unit | N | P | Model | Age (± 2σ) | L.I. |
|---|---|---|---|---|---|---|
| Peter Lake Domain | | | | | | |
| HUD83-19 | Granitoid | 11 | complex | | 2500 to 2780 | |
| (*)HUD85-25A | Grey megacrystic gneiss | 4 | 6 | 2 | 2582±19 | 933 |
| (*)HUD85-25B | Pink granitic gneiss | 3 | <1 | 2 | 2556±22 | 722 |
| (*)HUD85-25E | Granitic gneiss cutting 25B | 3 | 86 | 1 | 1860±5 | -10 |
| (*)HUD85-24 | Gabbro pegmatite | 2 | na | na | 1865±10 | |

Notes: N, Number of fractions; P, probability of fit (in percent); n.a., not available Model refers to models of Ludwig (1980, 1982) for models 1 and 2, and to Ludwig (1983) for model 4 Ages given in Ma, with uncertainties at 2-sigma. See text for further details.

New Results

Data from the Trans-Hudson Orogen

HUD 84-107 Fork Lake Pluton: Fork Lake (approx. Lat 55°50'N, Long. 104°16'W). Medium-grained alkali feldspar granite. Five zircon fractions yield an age of 1855±22 Ma.

HUD 84-108 Nistoassini-Nayelles Pluton: Collected by C. Livesey from the Upper Nistoassini Lake (approx. Lat. 56°18'N, Long. 103°52'W). Medium- to coarse-grained, mafic-rich granite. Five zircon fractions yield an age of 1853±10 Ma.

HUD 84-115 Numabin Bay Tonalite: From small island on the west branch of Numabin Bay (approx. Lat. 56°32'N, Long. 103°15'W. A strongly lineated medium-grained granodiorite. Four zircon fractions yield a well-constrained age of 1837±8 Ma.

HUD 84-117 Pegmatite, Nistoassini-Nayelles Pluton: This sample is a coarse-grained to pegmatitic biotite granite that cuts the Nistoassini-Nayelles Pluton. Four zircon fractions yield an age of 1859±11 Ma, analytically indistinguishable from the age determined for sample HUD 84-1087 (Nistoassini-Nayelles Pluton).

HUD 84-118 Kenwood Lake Pluton: From island in Kenwood Lake (approx. Lat. 56°17'N, Long. 104°07'W). This sample is of medium- to coarse-grained monzodiorite of the Kenwood Lake Pluton. Four zircon fractions yield an age of 1855±9 Ma.

HUD 84-134 Upper Waddy Lake Stock: From western shore of Upper Waddy Lake (approx. Lat. 56°12'N, Long. 103°53'W). This sample is of medium- to fine-grained hornblende granite. Three zircon fractions yield an age of 1834±13 Ma.

HUD 84-139 Contact Lake Pluton: From the shore of Lower Waddy Lake (approx. Lat. 56°10'N, Long. 103°47'W). The rock is a strongly foliated biotite granite. Five zircon fractions yield an age of 1853±16 Ma.

HUD 84-CL65 Wathaman Batholith: Collected by M. Meyer from Callin Lake (Lat. 56°46'N, Long. 104°35'W). Five zircon fractions yield an age of 1852±6 Ma.

HUD 84-ML07 Wathaman Batholith: Collected by M. Meyer at Mavis Lake (unofficial name) (Lat. 56°43'N, Long, 104°09'W). Granite to quartz monzonite. Five zircon fractions yield an age of 1862±4 Ma.

HUD 84-RL11 Wathaman Batholith: Collected by M. Meyer at Reilly Lake (Lat. 57°08'N, Long. 103°14'W). Granite to quartz monzonite. Eight zircon fractions yield an age of 1854±6 Ma.

HUD 84-WL03 Wathaman Batholith: Collected by M. Meyer at Wathaman Lake (Lat. 57°04'N, Long. 103°46'W). Four zircon fractions yield an age of 1855±6 Ma.

HUD 84-ML08 Wathaman Batholith: Collected by M. Meyer at Mavis Lake (Lat. 56°46'N, Long. 104°09'W). This sample is from an undeformed granitic sheet that crosscuts foliated main phase granite of the batholith. Four zircon fractions yield an age of 1830±6 Ma. The age places a lower limit on the time of deformation in this area.

Data from Saskatchewan Subsurface Samples

SASK-2 Tonalitic gneiss: From hole 8-30-8-33W1, extreme southeastern Saskatchewan. Hornblende-biotite tonalitic gneiss. Three zircon fractions yield an age of 1862±4 Ma, clearly indicating formation of the rock during a Hudsonian event.

SASK-8 Granulitic gneiss: From hole 9-22-45-12W2 in east-central Saskatchewan. The rock is a granulite facies gneiss of intermediate composition. Two zircon fractions indicate an age of 1786±4 Ma.

SASK-26 Granodioritic gneiss: From hole 8-8-64-2W3 in central Saskatchewan. Biotite-bearing tonalitic gneiss. Four zircon fractions indicate and age of 1914±50 Ma.

SASK-34 Posttectonic granite: From hole 2-21-16-17W3 in the Swift Current Anorogenic Province, southwestern Saskatchewan. Biotite granite. Three zircon fractions yield an age of 1763±4 Ma.

SASK-35 Charnockitic gneiss: From hole 7-14-56-17W3 in western Saskatchewan. Six zircon fractions yield an age of 2484±54 Ma, indicating that the sample is from a southerly extension of the Cree Lake Zone of the northwestern Churchill Craton.

SASK-48 Megacrystic granite: From hole 3-8-17-19W2 at Regina, south-central Saskatchewan. The rock is petrographically similar to granites of the Wathaman Batholith. Three zircon fractions yield an age of 1822±16 Ma, rather younger than most of the dated samples of the Wathaman (approx. 1855 Ma.).

Data from the Western Craton

HUD 85-1 Junction Granite: From Wasekamio Narrows between Wasekamio Lake and Turnor Lake (approx. Lat. 56°41'N, Long. 108°38'W) near the Virgin River Shear Zone in western Saskatchewan. The rock sampled is a medium- to coarse-grained biotite granite, strongly foliated with flaser structure. It postdates early blastomylonites of the Virgin River Shear Zone, for it contains xenoliths of these, and has been affected by later simple shear (Lewry, pers. comm., 1985).

Six zircon fractions have been analyzed so far. Four of these are magnetically fractionated bulk samples, all of which show varying amounts of older cores with overgrowths. These indicate an age of about 1820±10 Ma, probably a maximum for the event that caused the overgrowths. Two fractions which have been air-abraded to remove some or all of the overgrowths yield preliminary Pb-Pb ages of about 1890 Ma. It seems clear that the Junction Granite is an early Hudsonian intrusive, but it may have undergone a late Hudsonian metamorphism and it may also include inherited xenocrysts of older, perhaps Archean, zircons. This is a very important result, for it shows that Hudsonian events occurred far to the west of the volcanoplutonic part of the orogen. Bell and Macdonald (1982) had earlier reported a Rb-Sr age of 1760±40 Ma for the Junction Granite, which must clearly indicate an event later than the primary crystallization.

HUD 85-2 Blue quartz gneiss: From small island off the southwestern tip of Hill Island in Wasekamio Lake (approx. Lat. 56°44'N, Long. 108°52'W). The rock has been multiply deformed and metamorphosed. It has an early foliation with granulite facies mineral parageneses that have been redeformed by moderate to open folding with an associated axial planar fabric. Mineral assemblages were partially re-equilibrated in lower amphibolite facies during this later event. The zircons separated clearly show a bimodal population. One part of the population is composed of large deeply colored, euhedral to slightly rounded and corroded zircons, most of which show cores with pronounced overgrowths, whereas the other part is composed of small euhedral clear zircons. One fraction of the large and strongly colored population has yielded a $^{207}Pb/^{206}Pb$ age of 2290 Ma. We believe that this is a "hybrid" age, representing a mixture of older cores and younger overgrowth material. We are now in the process of air-abrading a sizeable sample of these zircons to remove as much of the overgrowth as possible. It seems likely that the age of the cores will be Archean. We have also analyzed one fraction of the smaller, clear fraction; it yielded a Pb-Pb age of about 2000 Ma, an age we believe must reflect a metamorphic event. This result should be important in deriving the primary age of this portion of the northwestern craton and also its metamorphic history.

HUD 85-8 Gneissoid inclusion in anorthosite: From east side of the north end of Fournier lake (approx. Lat. 57°04'N, Long. 108°26'W). This sample of granitic gneiss was collected from a very large inclusion (at least 100 $m^2$) in the Clearwater Anorthosite which has been multiply folded. The zircon population is complex, and analysis of five fractions indicates an age of approximately 2000 Ma. We will have to do a lot more work to sort out the complexities of the zircon population; however, we believe that the zircons have been reset by contact metamorphism and that the age indicated, 2000 Ma, is most likely the age of the anorthosite.

Data from the Peter Lake Domain

HUD 85-25A, B, E Granitic gneiss: From the Reindeer Lake shore southwest of Crane Island. The three samples of granitic gneiss here are complex, but show relative age by crosscutting relations. Sample 25A is a grey megacrystic gneiss that is evidently the oldest rock in the outcrop; it is cut by deformed mafic dykes. Four zircon fractions from the grey gneiss define an age of 2582±19 Ma. Sample 25B is a pink granitoid gneiss that cuts the grey gneiss and the mafic dykes; these zircon fractions define an age of 2556±22 Ma. These gneisses are thus of late Archean age. Sample 25E is also a pink granitic gneiss, but this rock crosscuts both the grey gneiss (25A) and the pink gneiss of sample 25B. Its age is 1860±5 Ma, as defined by three zircon fractions. This later pink gneiss is clearly of Hudsonian age. It may be an apophysis of

the Wathaman Batholith or a local anatectic granite related to Hudsonian orogenesis.

HUD 85-24 Gabbroic pegmatite: From shore of Reindeer Lake southwest of Crane Island. Pegmatitic phase of a layered hornblende gabbro. Two zircon fractions indicate an age of 1865±10 Ma. We believe that this is a most significant result, for it indicates that mafic rocks were formed within the Peter Lake Domain during the Hudsonian orogeny.

New Samples Collected in 1986

Our main sample collecting during the summer of 1986 was designed primarily to elucidate age relations in the eastern and southeastern portions of the Trans-Hudson Orogen. We collected from three adjoining regions:

1) the Flin Flon area, to try to determine a more precise chronology for the Flin Flon arc;
2) the Hanson Lake area to try to resolve a difference between our age of 1888±12 Ma for a metarhyolite we collected there in 1983 (HUD 83-9) and the ca. 2450 Ma Rb-Sr result reported earlier by Coleman (1970), and in order to try to locate more Archean material to substantiate the late Archean dates from the Sahli Granite; and
3) the Kisseynew Domain to begin establishing a chronology.

Two further samples were also collected from the La Ronge Domain and two from the Glennie Lake Domain.

La Ronge Domain

HUD 86-1 Jepson Lake Pluton: From Stanley Mission Road, 10.5 km northeast of junction with Highway 102. Highly foliated biotite-hornblende granite, to assess age relative to the plutons of the Central Metavolcanic Belt. The Jepson Lake Pluton could possibly be basement.

HUD 86-31 Round Lake Stock: Collected by C.T. Harper from road side about 1500 m south of the Komis deposit. Leucogranite rich in distinctive blue quartz, categorized as late tectonic (Harper's Group 3) yet resembling by its blue quartz some of the rhyolites in the area.

Glennie Lake Domain

HUD 86-29 Feldspar porphyry: Collected by G.D. Delaney from Laonil Lake area. Associated with gold-bearing quartz-tourmaline veins (Vein 13) in shear zones and may give date of mineralization.

HUD 86-30 Quartz diorite, Laonil Lake Intrusive Complex: Collected by G.D. Delaney from Laonil Lake. This rock is one of the later intrusive phases and should give a minimum age for the complex.

Flin Flon Area

In the Flin Flon area we sampled from the Amisk Group volcanics and their presumed synvolcanic plutons, from the Boundary Intrusives that cut the volcanics, and from several late plutons that cut both the Amisk Group volcanics and the molassic sedimentary rocks of the Missi Group.

HUD 86-2 Cliff Lake Pluton: From close to Manitoba-Saskatchewan border, northeast of Flin Flon. "Blue quartz-eye" granite or granodiorite believed to be synvolcanic with Amisk Group volcanic rocks.

HUD 86-3 Quartz-phyric rhyolite: From the east shore of Phantom Lake. Quartz phenocrysts are abundant in this sample of Amisk Group rhyolite. In nearby outcrops this rock is intruded by the Boundary Intrusives.

HUD 86-4 Phantom Lake Pluton: From the west shore of Phantom Lake. A fresh porphyritic granite with K-feldspar phenocrysts up to 1 cm in length. This rock is undeformed and cuts both the Boundary Intrusives and the Amisk Group volcanics.

HUD 86-5 Biotite-diorite of Boundary Intrusives: From the northwest shore of Phantom Lake. The "orange phase" of the boundary intrusives, it intrudes an earlier more mafic diorite or gabbro, also considered part of the Boundary Intrusives.

HUD 86-6 Quartz-phyric rhyolite: From the east side of Creighton Township. This rhyolite from "the mine horizon", Amisk Group is extremely fine grained and appears glassy. It has abundant partly resorbed quartz phenocrysts, but feldspar phenocrysts are not evident.

HUD 86-7 Feldspar-quartz-phyric rhyolite: From the West Arm Mine Road. This sample of Amisk Group rhyolite has abundant phenocrysts of both feldspar and quartz. The quartz phenocrysts are bluish and up to 3 mm in diameter.

HUD 86-8 Boot Lake Pluton: From the West Arm Mine Road. This sample is of the inner porphyritic phase of the hornblende-biotite granite of the Boot Lake Pluton, which cuts Amisk Group volcanics and is itself cut by the Phantom Lake Pluton (HUD 86-4).

HUD 86-22 Quartz-phyric ash flow tuff: From Hyslin Bay, Missi Island. Contains abundant quartz and feldspar phenocrysts.

HUD 86-23 Quartz diorite porphyry: From Missi Island, Missi Bay, Amisk Lake. This sample contains abundant large bluish quartz phenocrysts and biotite and is believed to be a subvolcanic

pluton coeval with and related to the Amisk Group volcanics.

HUD 86-24 Andesite or dacite: From Errington Lake. We collected a small sample of this rock to test whether enough zircon could be obtained for a good age determination. The sample is part of the West Amisk volcanic sequence.

HUD 86-25 Quartz Diorite, Neagle Lake Pluton: The rock mass is unfoliated, crosscuts the late West Channel Fault System, and may be a very late pluton in the Flin Flon arc.

HUD 86-26 Foliated granite to granodiorite, Annabel Lake Pluton: From the west end of Annabel Lake. Sample is from the Annabel Lake Pluton, at the transitional junction with the Kisseynew Domain.

HUDS 86-27 Granodiorite of the Reynard Lake Pluton: From a road cut between Creighton and Denare Beach. The rock is granodiorite with large K-feldspar megacrysts, bluish quartz, biotite and plagioclase. This body cuts the molassic sedimentary rocks of the Missi Group.

HUD 86-28 Strongly foliated granodiorite of the Johnson Lake Pluton: From a roadcut on Highway 106, 23.5 km west of Creighton. Sample was collected at a point where the pluton could be considered to be transitionally within the Kisseynew Domain.

Kisseynew Domain

HUD 86-9 Biotite granodiorite of Tyrrell Lake Pluton: From north end of Tyrrell Lake. This medium- to coarse-grained phase of the pluton shows folding. We were unable to collect an unequivocal sample of a later fine-grained phase.

HUD 86-10 Mari Lake Granodiorite: From west side of McCormick Lake. The rock is a very fresh and strongly foliated granodiorite, probably from close to the margin. The body is essentially pretectonic, and might be basement to contiguous Kisseynew supracrustals (see Macdonald, 1975).

HUD 86-11 Pegmatite: From north end of Caledon Lake. The sample is a coarse undeformed pegmatite possibly produced during late anatexis. The reset date from here would probably give a peak metamorphic/anatexis age for the Kisseynew event.

HUD 86-12 Meta-arkose: From Kipahigan Lake. The meta-arkose contains quartz, feldspar, biotite and sillimanite, and is presumably of Sheridan/Missi age. Zircon separates from this sample will presumably be of detrital material and may shed light on the provenance of the Sheridan rocks.

HUD 86-13 Granodioritic gneiss: From southern part of Mari Lake. This rock is strongly but fairly uniformly foliated and unevenly banded, containing felsic layers. Interpreted variously as a strongly deformed pluton or supracrustal rock. Age and zircon studies may help resolve this problem.

Hanson Lake Block

HUD 86-14 Jackpine Lake Granodiorite: From west shore of Jackpine Lake. Collected to test the Rb-Sr results of Coleman (1970) who obtained an age of about 2500 Ma from rocks in this region, including the granodiorite of Jackpine Lake. Our sample is of an inclusion-free portion of the strongly foliated granodiorite that is cut by numerous pegmatites. It has been speculated that the body may be basement (ca. 2500 Ma) to contiguous supracrustals.

HUD 86-15 Biotite granodiorite: From the west shore of Bertram Bay, Hanson Lake. A biotite granodiorite that should be from the same locality as Coleman's (1970) sample 54. As with HUD 86-14, the sample was collected to test Coleman's Rb-Sr results.

HUD 86-16 Fragmental dacite: From the southeast shore of Bertram Bay, Hanson Lake. The sample was collected from the site of Coleman's (1970) sample 51. The rock is clearly a fragmental felsic volcanic but it is now fairly strongly deformed with a subschistose matrix. Lithic fragments and probable phenocrysts are stretched. Quartz grains, commonly elongate, are abundant and may represent old quartz phenocrysts. Garnet porphyroblasts are present.

HUD 86-17 MacGuire Lake Granite: From the southern end of MacGuire Lake. The sample resembles a trondjhemite-tonalite. Many large partially digested inclusions of mafic supracrustal rocks are present. This unit is interpreted as a late neosomal, and possibly fundamentally anatectic, phase of the Kisseynew complex in this region. We anticipate obtaining a complex zircon population from this sample.

HUD 86-18 Wuskwiatik Pluton: From the west end of Wuskwiatik Lake. The rock is uniform and a mostly massive foliated biotite granodiorite, almost free of inclusions. The pluton has a circular outline suggestive of late intrusion, yet is uniformly foliated. Relation to the Kisseynew anatexis is uncertain.

HUD 86-19 Jan Lake Granite suite: From an island on Jan Lake. The rock collected is representative of the coarse to pegmatitic granite that forms post-tectonic aplitic to pegmatitic sheets in this region.

HUD 86-20 Foliated quartz diorite: From Jan Lake. The sample is of a grey biotite-rich

granodioritic to quartz-dioritic rock that evidently crosscuts folded earlier felsic gneisses yet has a weak foliation of its own. A zircon date should give a late tectonic age, but earlier than the fully post-tectonic Jan Lake Granite suite.

HUD 86-21 Meta-arkose: From Jan Lake. The sample is of a banded biotite gneiss with abundant magnetite concentrated in layers, and is evidently a meta-arkose (rare consensus of geologists). It was collected for separation of detrital zircon, possibly to determine the age of source rocks for these immature sedimentary accumulations. The collecting site is near the Macmillan Point Granite, which forms an apparent gneiss dome surrounded by stratified metasedimentary rocks. The Macmillan Pointe Granite has yielded a zircon population which has given preliminary zircon ages suggesting an Archean inheritance.

## Acknowledgements

The geochronological work is supported by Grant EAR 9313167 from the National Science Foundation of the United States Government. Field and logistical support are provided by Saskatchewan Energy and Mines. We are grateful for stimulating exchanges with K. Bell, Carleton University, Ottawa, and K.D. Collerson, University of California, Santa Cruz.

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Project 8607B

# Preliminary Results from U-Pb Zircon Geochronology of the Uranium City Region

by W.R. Van Schmus[1], S.S. Persons[1], R. Macdonald and T.I.I. Sibbald

Van Schmus, W.R., Persons, S.S., Macdonald, R. and Sibbald, T.I.I. (1986): Preliminary results from U-Pb zircon geochronology of the Uranium City region, northwest Saskatchewan; in Summary of Investigations 1986, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 86-4.

Samples were collected in the Uranium City region during the 1984 field season in order to examine several problems related to the regional geologic history (Macdonald, 1984; Macdonald and Slimmon, 1985). The ages reported here represent initial results pertinent to three of these problems: (1) age of the Nolan Block, northwest of Uranium City, (2) age of Early Proterozoic plutons intrusive into older Proterozoic and/or Archean basement in the Beaverlodge Area along the north shore of Lake Athabasca, and (3) age of suspected Archean basement in the Beaverlodge Area. The general geology and sample locations are shown in Figure 1. The sample locations and ages obtained are summarized in Table 1.

## Nolan Block

The Nolan Block is the only segment of the Precambrian Shield in Saskatchewan which has produced K-Ar dates in the range 2100 to 2400 Ma (Koster and Baadsgaard, 1970), and is therefore considered very likely to comprise largely unreworked very early Proterozoic or Archean material. In order to test this premise, samples were collected from the north shore of Tazin Lake on the southern margin of the block and from Nolan Lake in the centre of the block in Saskatchewan. The area was mapped by Koster (1966, 1967), but no recent work has been done in the area.

The shoreline exposure at Tazin Lake comprises a multiphase plutonic complex at amphibolite facies grade. We sampled the dominant granitic gneiss (HUD84-304), two granodioritic xenoliths about 30 cm in size (HUD84-302, -303), and a granitic dyke intruding the granitic gneiss (HUD84-301).

The characteristics of the granitic gneiss, including the presence of garnets, suggest that its protolith was an arkosic metasediment, but this is not certain. Two zircon fractions from this rock define a chord with an upper intercept on concordia of 2639±16 Ma. The upper intercept on concordia is an apparent age only and is open to the following interpretations: 1) The zircons represent a relict detrital population with a mean age of 2639 Ma; the source would contain zircons at least 2639 Ma old for the oldest component and no older than 2639 Ma for the youngest component, and the age of sedimentation can be no older than 2639 Ma. 2) The zircons represent magmatic zircons in an orthogneiss and suggest a primary crystallization age of ca. 2639 Ma. 3) The zircons are metamorphic and indicate that the protolith must be at least 2639 Ma old.

The zircons from the granitic dyke define a very good chord with an upper intercept on concordia of 2595±7 Ma; we interpret this age as the crystallization age for the granitic dyke.

The xenolith samples were relatively small and yielded fewer zircons, so that only two fractions were analyzed from each. However, the data from these samples are fully consistent with the age defined by the granite of the dyke. This indicates either that the xenoliths are slightly earlier phases of the granitic activity represented by the dyke, or that the zircons in the xenoliths were completely reset due to the heat of the host granite; we prefer the first alternative, but cannot rule out the second one.

There is no evidence that the granite gneiss is substantially older than the granitic dyke. The time around 2600 Ma must have been one involving major igneous and/or thermal activity in the region.

One sample was collected on the west shore of Nolan Lake (HUD84-305). The rock is a uniform coarse grained to megacrystic granitoid. There is little evidence of deformation or recrystallization, and the zircons display igneous morphology and zoning. Zircons from this granite define a very good chord with an upper intercept on concordia of 2581±Ma. We interpret the upper intercept for this rock as giving the crystallization age of the pluton. This age is slightly younger than those from the Tazin Lake locality. The similarity in ages indicates that the Nolan Lake rock was intruded during the same general period of igneous activity. The slight age difference indicates that tectonic deformation had ceased by ca. 2580 Ma.

These ages of 2580 to 2600 Ma are similar to others found in the region. Stevenson and Cumming (1986) reported similar ages not too far north, in the Northwest Territories, and Van Schmus et al. (1986), Ray and Wanless (1980), and Bickford et al. (1986) have reported ages of ca. 2600 Ma for units

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Project funded under the Saskatchewan component of the Canada-Saskatchewan Subsidiary Agreement on Mineral Development 1984-89.

Table 1 - Summary of samples, locations and U-Pb ages

| Sample No. | Description and Location | N | P | Age ± 2 Sigma |
|---|---|---|---|---|
| **Tazin Lake Area** | | | | |
| HUD84-301 | Granitic dyke intruding older gneiss, north shore of Tazin Lake | 4 | 99 | 2595 ± 7 |
| HUD84-302 | Granodiorite xenolith in granite of dyke (HUD84-301), north shore of Tazin Lake | 2 | - | 2596 ± 10 |
| HUD84-303 | Granodiorite xenolith in granite of dyke (HUD84-301), north shore of Tazin Lake | 2 | - | 2605 ± 10 |
| HUD84-304 | Granitic gneiss, host of granite dyke (HUD84-301), north shore of Tazin Lake | 2 | - | 2639 ± 16 |
| HUD84-305 | Megacrystic granodiorite, west shore of Nolan Lake | 4 | 90 | 2581 ± 4 |
| **Beaverlodge Area: Early Proterozoic Plutons.** | | | | |
| HUD84-307 | Mackintosh Granite, Caldwell Bay, north shore of Lake Athabasca | 5 | 76 | 2356 ± 14 |
| HUD84-315 | Granite, Gunnar Mine, north shore of Lake Athabasca | 6 | 29 | 2181 ± 5 |
| HUD84-31 | Box Mine Granite, Box Mine | 5 | <1 | 1994 ± 37 |
| HUD84-322 | Athona Mine Granite | 5 | 2 | 2327 ± 17 |
| **Beaverlodge Area: Archean Basement.** | | | | |
| HUD84-319 | Elliot Bay Granite | 5 | 1 | 3014 ± 10 |
| HUD84-325 | Lodge Bay Granite | 5 | <1 | 3072 ± 41 |

Notes:
N = number of zircons defining chord
P = Probability of Fit (percent); omitted for chords with 2 points
Ages in Ma; Upper intercept ages determined from regression program of Ludwig (1983), Model 1 used for P>30, Model 2 used for P<30.

of the Peter Lake Domain along the southeast margin of the reworked Archean craton to the south. Consequently, the period around 2600 Ma ago must have been very important in the thermal-tectonic evolution of this part of the Churchill Craton.

## Early Proterozoic Plutons of the Beaverlodge Area

Samples were collected from several of the early Proterozoic plutons that intrude older Proterozoic and Archean units in the Beaverlodge area, north shore of Lake Athabasca. At the time of collection, it was thought that these 'North Shore Plutons', including the ones associated with the gold mines of the Goldfields district (Sibbald, 1984), were related. Our results (Table 1) show, however, that relationships are not simple.

The Mackintosh Granite and the granite at the Athona Mine are coarse and megacrystic granites. Although both have discordant contacts in places, these contacts are usually somewhat gradational, with a zone of pervasive assimilation or granitization up to several tens of metres wide. Zircons from these two units (HUD84-307, -322) yield similar ages of 2356±14 and 2327±17 Ma. These ages barely overlap within the stated uncertainties, and an intermediate age of ca. 2340 Ma may be more representative.

The Cameron Island Granite, which has yet to be dated by the U-Pb Zircon method, is similar in some respects to the MacKintosh and Athona granites, but its margins appear to have been modified by subsequent deformation.

The sample of granite at the Gunnar Mine is lithologically similar to the Mackintosh and Athona granites. The sample (HUD84-315) yielded a slightly younger upper intercept on concordia of 2181±5 Ma based on current data. However, some of the zircon fractions from this unit plot significantly above concordia, a feature which is quite unusual but seems to be real. We are conducting further analyses in attempt to verify and explain this behavior.

The auriferous granite at the Box Mine is a distinctive pink medium grained rock associated with numerous quartz veins and considered generally to be derived by granitization of quartzitic supracrustals. This metasomatism may have been associated with hydrothermal activity to produce the regional gold mineralization. Zircons from this narrow unit yielded an upper intercept on concordia at 1994±37 Ma, the youngest U-Pb zircon age so far found in the region. The zircons may have formed during the period of hydrothermal activity. In this regard, it is interesting to note that the zircons from the Box Mine unit have very high uranium contents (1000 to 3000 ppm). Zircons from the other units covered in this report have significantly lower U-contents of 200 to 800 ppm, consistent with a high-temperature (magmatic) origin. The high U-contents of the Box Mine zircons therefore would be consistent with formation at lower (hydrothermal) temperatures, although they do not prove it.

Bell and Bikerman (1985) have summarized the current state of Rb-Sr studies in this region, and they have found that the North Shore Plutons yield Rb-Sr isochrons with ages of ca. 2000 to 2050 Ma. This is distinctly younger than the U-Pb ages for the Mackintosh and Athona granites,but comparable to the U-Pb age for the granite at the Box Mine. If the region was subjected to major hydrothermal activity about 2000 Ma ago, it is posssible that this event was responsible for resetting the Rb-Sr systems in the older granites.

In summary, we interpret the current data for the North Shore Plutons to signify that granitic plutonism occurred about 2340 and 2180 Ma ago and that this was followed by a later period of hydrothermal activity and metasomatism, accompanied by gold mineralization, about 2000 Ma ago. Further analytical work may, however, lead to other interpretations.

## Archean Basement of the Beaverlodge Area.

Attempts have been made over many years to locate a basement to the Murmac Bay Group which outcrops along the north shore of Lake Athabasca. In 1984 an apparent granite-wash unconformity was discovered by S. Roscoe (GSC) and one of the authors at the postulated base of the Murmac Bay Group (Macdonald, 1984) about 1000 m northeast of Elliot Bay. The granite appears on the map to be a narrow extension of the Lodge Bay granite. In 1985 a re-examination of the Lodge Granite/Murmac Bay contacts suggested a modified basement/cover relationship.

Samples were taken for U/Pb zircon determination from the Elliot Bay exposure (HUD84-319) and from the Lodge Bay Granite (HUD84-325).

The data for each of these samples scatter slightly, giving a poor probability of fit, and the two ages do not overlap within the stated uncertainties (Table 1). However, both ages are similar, at about 3040 Ma, and this is probably a good estimate of the age of the pre-Murmac Bay basement.

This unit is clearly the oldest one found in the region so far, and it indicates that this part of the Churchill Craton had a long history in the Archean, even though there appears to be extensive late Archean igneous and metamorphic activity at ca. 2600 Ma, as described above.

The age of ca. 3040 Ma, in conjunction with an age of ca. 2340 Ma for the older North Shore Plutons, brackets the age of the Murmac Bay Group, although it does not discriminate as to whether they are Archean or Proterozoic. Additional studies on the metasedimentary rocks themselves may be necessary to resolve their stratigraphic position.

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Appendix: Sample Locations

HUD84-301: Granodiorite dyke cutting foliated gneiss, north shore of Tazin Lake.

HUD84-302: Granodiorite xenolith in granodiorite dyke of HUD84-301.

HUD84-303: Granodiorite xenolith in granodiorite dyke of HUD84-301.

HUD84-304: Granodiorite gneiss, north shore of Tazin Lake.

HUD84-305: Coarse-grained granodiorite, west shore of Nolan Lake.

HUD84-307: Mackintosh Granite, west shore of Caldwell Bay, Lake Athabasca.

HUD84-315: Coarse-grained foliated granite, Gunnar Mine.

HUD84-317: Coarse-grained granite, Box Mine, Goldfields area.

HUD84-319: Coarse-grained gneissic granite, below unconformity with Murmac Bay Group, near Elliot Bay, Lake Athabasca.

HUD84-322: Coarse-grained granite, Athona Mine, Goldfields area.

HUD84-325: Coarse-grained Lodge Bay granite southwest of road to Lodge Bay.

Project 8607C

# A U-Pb Zircon Date for the Ennadai Group

by J.R. Chiarenzelli[1] and R. Macdonald

Chiarenzelli, J.R. and Macdonald, R. (1986): A U-Pb zircon date for the Ennadai Group; in Summary of Investigations 1986, Saskatchewan Geological Survey; Saskatchewan Energy and Mines; Miscellaneous Report 86-4.

The Ennadai Group is the name adopted for an assemblage of metavolcanic and associated supracrustal rocks which occur in the vicinity of Hattle Lake, near the northern Saskatchewan border northeast of Stoney Rapids (NTS area 64M-14) (Fig. 1). The rocks at Hattle Lake represent the southernmost outcrop of an assemblage which extends northwards into the Northwest Territories through Snowbird Lake (Taylor, 1973). Similar rocks occur in a separate basin further northeast of Snowbird Lake where they have been termed the Hanik Group (Eade, 1974), and the Ennadai Group possibly also correlates with the Kaminak Group which has yielded late Archean dates (Stockwell, 1963).

## Geology

The rocks around Hattle Lake were described briefly by Macdonald (1984). In summary, they comprise mafic to intermediate metavolcanics with many pillowed flows, and a variety of volcaniclastic rocks. These rocks lie generally in a regional-scale synform and are succeeded in the core of this synform by volcanogenic metasediments, including iron formation. Although the metamorphic grade is generally about lower amphibolite facies, deformation is relatively low. Contiguous granitic rocks appear to be representative of high-level plutons, and there is no indication of a basement.

## Sample Data

The sample for age determination was collected from a rare rhyolitic rock which occurs in a band about one to two metres thick within the flow succession immediately southeast of Hattle Lake itself. The sample is unaltered, pinkish grey, fine grained and contains potassium feldspar and quartz phenocrysts. There is little sign of deformation.

## Analytical Techniques

The analytical data (Table 1) were determined at the Isotope Geochemistry Laboratory, K.U. Center for Research, University of Kansas. Techniques used were similar to those given in Van Schmus et al. (in press). Two zircon fractions were air-abraided. Results are reported using Ludwig's (1980, 1983) Model 1 solution (essentially York, 1969) and ages are quoted at the 2-sigma level.

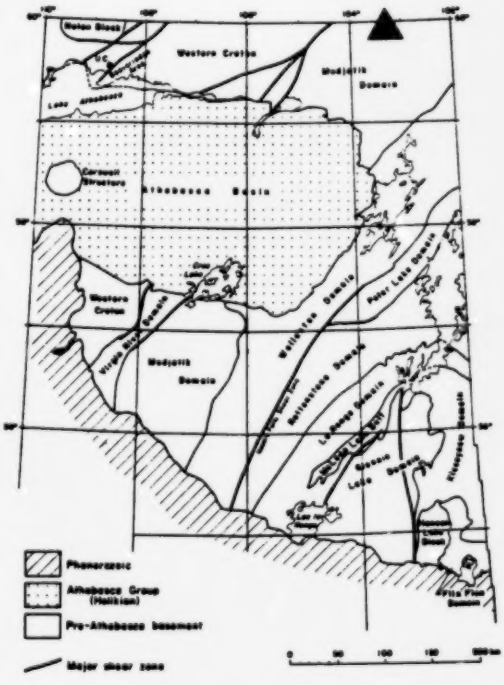


Figure 1 - Location of the Ennadai Group (solid triangle).

## Results

The sample yielded euhedral to anhedral zircons averaging 0.2 mm in size, the bulk of which are stubby dipyramids. Almost all show fine concentric growth zoning typical of felsic volcanic rocks, and about half are heavily fractured. Some zircons contain needle-like inclusions of an unidentified mineral.

These zircons give an upper intercept age of 2682±5.9 Ma (Fig. 2). The age is consistent with predictions and with the ages obtained from similar

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**Table 1 - Analytical Data from Zircon Fractions**

| Fraction | Concentrations U (ppm) | Concentrations Pb (ppm) | Pb Isotopic Composition Pb-204/Pb-206 | Pb-207/Pb-206 | Pb-208/Pb-206 | Radiogenic Ratios Pb-206/U-238 | Pb-207/U-235 | Pb-207/Pb-206 | Ages Pb-206/U-238 | Pb-207/U-235 | Pb-207/Pb-206 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| M(-2)aa | 176 | 106 | 0.00010 | 0.18398 | 0.18264 | 0.5130 | 12.928 | 0.18278 | 2669 | 2674 | 2678 |
| M(-1)aa | 203 | 123 | 0.00035 | 0.18669 | 0.19720 | 0.5063 | 12.730 | 0.18237 | 2641 | 2660 | 2675 |
| NM(-2) | 168 | 106 | 0.00194 | 0.20447 | 0.23833 | 0.4957 | 12.366 | 0.18093 | 2595 | 2632 | 2661 |
| M(-2) | 179 | 105 | 0.00045 | 0.18670 | 0.18902 | 0.4931 | 12.319 | 0.18120 | 2584 | 2629 | 2663 |
| M(0) | 227 | 127 | 0.00029 | 0.18240 | 0.18702 | 0.4749 | 11.709 | 0.17883 | 2502 | 2581 | 2642 |

rocks in the Northwest Territories (Stockwell, op. cit.), and is interpreted as the primary crystallization age of the rhyolite.

## Acknowledgment

The authors thank J.A. McNutt and D. Jiricka (Saskatchewan Mineral Development Corporation) who facilitated the collection of the sample and provided geological input during the field visit.

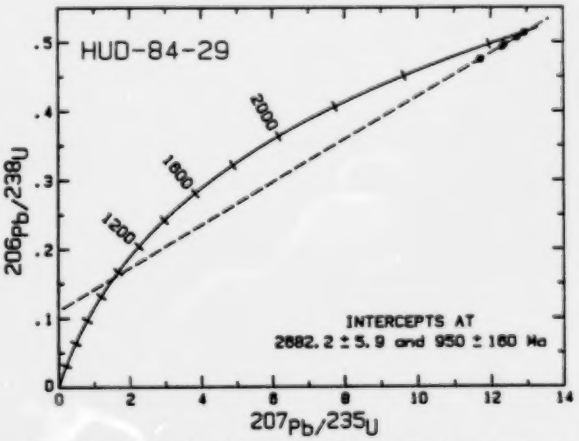


**Figure 2 - Concordia diagram for zircon fractions from a rhyolite in the Ennadai Group. Open circles are air-abraided points.**

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Project 8603

# Conglomerate Composition, Source Areas and Dispersal in the Depositional Basin of the Martin Group

by P.K. Mazimhaka[1] and H.E. Hendry[1]

Mazimhaka, P.K. and Hendry, H.E. (1986): Conglomerate composition, source areas and dispersal in the depositional basin of the Martin Group; in Summary of Investigations 1986, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 86-4.

Field studies of the Martin Group in the 1986 season were conducted throughout the Greater Beaverlodge area, in the Martin Lake Basin, the Charlot Point Basin, the Tazin Lake Basin, and in the Gravel Islands and Gruchy Bay areas. Modal analyses of conglomerates and palaeocurrent analyses were aimed at identifying source areas for the Martin sediments and at reconstructing sediment dispersal patterns.

## Conglomerate Composition and Source Area

Conglomerate analysis was done by point-counting clast types on an outcrop grid. A grid with a 20 cm spacing was used to avoid having too many points per clast in the coarser conglomerates. The number of points recorded at any one locality was limited in small outcrops, but ranged from 80 to 240. Attempts were made to record data from a wide range of geographic localities and from beds throughout the stratigraphic section. Where field counts could not be made because the conglomerates were poorly exposed or fine-grained, individual clasts or slabs were collected for laboratory analysis.

Previous studies of clast composition in the Martin Group rocks of the Greater Beaverlodge area identified an igneous/metamorphic source terrain for rocks of the Martin Lake Basin and for the Taz Bay Formation, and a predominantly sedimentary source area for the Charlot Point Formation (Tremblay, 1972; Macey, 1973; Langford, 1981).

Macey (1973) analysed conglomerates in the Beaverlodge area, mainly near Lorado Mill. He noted "a large variation in clast lithology even among localities which are not widely separated ... the diversity reflects derivation from a complex source" (Macey, 1973, p. 12). Tremblay (1972) observed that clasts were derived from all Tazin Group rocks, but that quartzite, granite, and granite-gneiss clasts were most abundant. Langford (1981) reported that clasts in the Seaplane Base Formation of the Martin Lake Basin, as well as those in the Taz Bay Formation of the Tazin Lake Basin, are mainly basement gneiss.

### Charlot Point Formation

Clasts in the Charlot Point Formation are predominantly of sedimentary rocks (Langford, 1981; Mazimhaka and Hendry, 1985). Langford (1981) suggested that these clasts were derived from the Jug Bay and Beaverlodge Formations, and not from the underlying Thluicho Group because "the majority of rock types in the Thluicho Group, including felsic volcanics, argillite and sandstone, are not represented in the clasts". Locally (e.g., on Slate Island) the clasts include thinly bedded angular blocks derived from the underlying argillites of the Thluicho Group. At the tip of Camsell Peninsula (Mazimhaka and Hendry, 1985, Fig. 2, locality 257), clasts in thin conglomerate beds consist of rusty brown sandstones with a cream- to orange-weathering rim, some conglomerates, and igneous or metamorphic rocks. The igneous or metamorphic clasts might have been derived from conglomerates. In the Charlot Point section (Mazimhaka and Hendry, 1985, Fig. 2) sandstone and pebbly sandstone clasts are reddish-brown with grey or green colour-banding and clasts in the pebbly sandstones are mainly quartz and granite or granite gneisses. Some siltstone clasts, most of them reddish-brown, occur in the lower part of the Boulder Beach section (Mazimhaka and Hendry, 1985, Fig. 2, localities 263 and 264). On the basis of field evidence, clasts in the Charlot Point Formation could have been derived from the Jug Bay, Beaverlodge, Ellis Bay (Scott 1978) and Taz Bay Formations, as well as from the Thluicho Group. Results of the modal analyses are presented in Table 1.

### Beaverlodge Formation

Beaverlodge Formation sample localities 120, 332, 333, 334 and 106 lie northeast of Beaverlodge Lake (Fig. 1). The basement north, east and south of the Martin Group outcrop in this area is dominated by six units mapped and described by Tremblay (1972).

North of the Saint Louis Fault, the basement consists of dirty grey quartzite and chlorite sericite schist (Tremblay's unit 3) and argillite and

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Project contracted to the University of Saskatchewan with funds provided under the Saskatchewan component of the Canada-Saskatchewan Subsidiary Agreement on Mineral Development 1984-89.

Table 1 - Modes of Conglomerates for the Beaverlodge, Seaplane Base, Gillies Channel, Taz Bay and Gravel Islands Formations

| Sample Locality | 120 | 332 | 333 | 334 | 106 | 50 | 84 | 70 | 28 | 202 | 353 | 310 | 311 | 312 | 299 | 74b | 74b | 421 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Granite gneiss | 16 | 5 | - | - | 34 | 40 | 69 | 11 | 4 | 41 | 63 | - | - | 29 | 18 | 9 | 8 | 49 |
| Granoblastic | - | - | - | - | - | - | - | - | - | - | - | 95 | 52 | - | - | - | - | - |
| Foliated gneiss | - | - | - | - | - | - | - | - | - | - | - | - | 27 | 51 | 16 | - | - | - |
| Amphibolitic gneiss | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 3 | - | - | - |
| Garnet gneiss | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 44 | - | - | - |
| Granite | 2 | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | 6 | - | - |
| Mafics | 26 | 16 | 35 | 33 | - | 6 | 1 | - | 10 | 2 | - | 1 | 13 | 15 | 6 | - | 1 | 1 |
| Quartz | 14 | - | - | - | 8 | 15 | 5 | - | 7 | 26 | 4 | 4 | 9 | - | 6 | 50 | 28 | 17 |
| Schists | - | 5 | 2 | 5 | 9 | - | - | 10 | 5 | - | - | - | - | - | 8 | - | - | - |
| Quartzite | 41 | 73 | 63 | 62 | 49 | 35 | 24 | 77 | 62 | 15 | 21 | - | - | 4 | - | - | 18 | 2 |
| Sandstone | - | - | - | - | - | - | 1 | - | - | 15 | 3 | - | - | - | - | 26 | 33 | 23 |
| Siltstone | - | - | - | - | - | 3 | 1 | - | 12 | - | 10 | - | - | - | - | 4 | 4 | 1 |
| Conglomerate | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | - |
| Other | - | - | - | - | - | - | - | 1 | - | - | - | - | - | 1 | - | 6 | - | 6 |
| n | 152 | 154 | 174 | 204 | 172 | 204 | 241 | 82 | 143 | 82 | 105 | 187 | 230 | 151 | 137 | 88 | 229 | 82 |

hornblende schist (unit 4). These two units crop out together with the ubiquitous metasomatic granite (unit 19) which is gneissic in this area.

South of the St. Louis Fault, the units outcropping comprise up to seven varieties of quartzites with a wide range of colours, texture and composition (unit 6), amphibolite and hornblende schist (unit 7) and quartz biotite schists (unit 8).

In all sampled conglomerates in this area, more than 40 percent of the clasts are quartzite. At locality 106, there are more granite gneiss clasts than in the other four localities located to the southwest and stratigraphically higher in the formation. No mafic rocks are recorded at locality 106, but at the other four, mafic clasts (mainly amphibolite) constitute between 16 and 35 percent of recorded clasts. It appears therefore, from clast composition and distribution of basement rock types, that the source area lay to the northeast, east and southeast.

South of Beaverlodge Lake, the basement consists of five units mapped by Sibbald and Lewry (1980):

1) quartzite, gritty quartzite quartzofeldspathic conglomerates (unit 1);
2) mica and graphitic schists (unit 3);
3) dark green amphibolite, probably of volcanic origin (unit 5);
4) granites and granite gneisses (unit 7); and
5) grey to pink to brick red intrusive granitic rocks (unit 8).

Conglomerates at locality 70 (Fig. 1), north of the Lorado Mine, rest on a band of south-striking mica and graphitic schists less than 2000 m wide. There are granite gneisses to the east, and quartzites to the west and northwest (units 3, 7 and 1, respectively of Sibbald and Lewry, 1980). Seventy-seven percent of the clasts at this locality are quartzite and the rest are equally distributed between granite gneisses and schists suggesting a local source to the south and southwest.

At locality 50 (Fig. 1), the conglomerates are stratigraphically higher than those at locality 70. The basement in this area consists of quartzite, amphibolite and granite gneisses (units 1, 5 and 7 of Sibbald and Lewry, 1980). Gneisses and quartzite constitute 75 percent of the recorded clasts.

Basement lithology around locality 84 (Fig. 1), south of Nero Lake, is dominated by metasomatic granite (unit 19 of Tremblay, 1972) and the Cayzor Unit which consists of impure feldspathic quartzite, schists, gneisses and augen gneisses and massive granite (unit 17 of Tremblay, 1972). Unit 19 crops out to the north and west, and unit 17 to the south. The conglomerates here contain 69 percent granite gneiss and 24 percent quartzite clasts. The high proportion of granite gneiss suggests a northwesterly to westerly source for the conglomerates at locality 84.

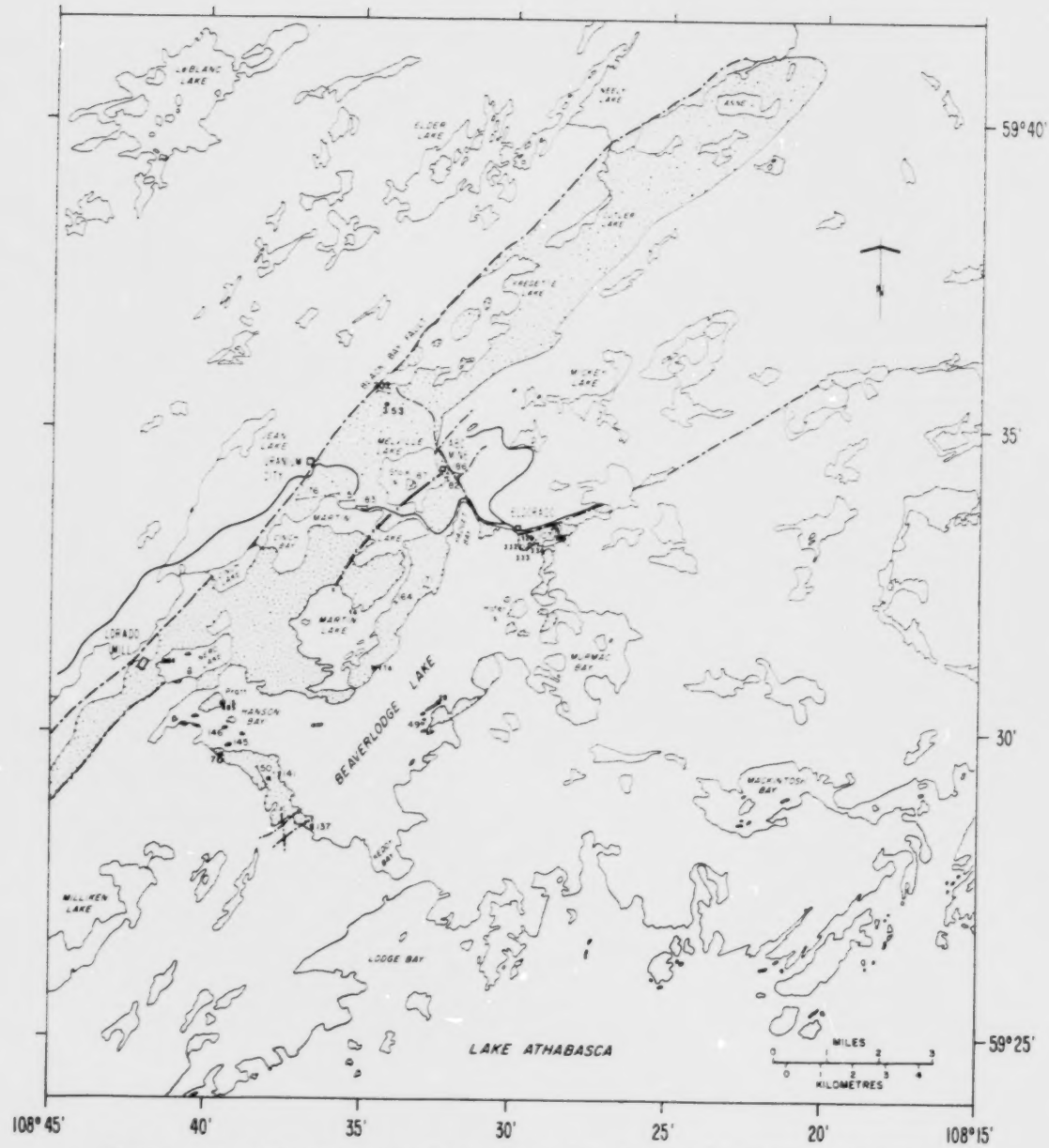


**Figure 1 - Map of the study area showing sections and sample localities referred to in text.**

## Gillies Channel Formation

The Gillies Channel sample is from locality 28 (Fig. 1). The basement east of locality 28 is underlain by the same rocks described above for the area south of the St. Louis Fault (units 6, 7 and 8, with some exposures of unit 19 of Tremblay, 1972). Quartzite makes up 62 percent of all recorded clasts. Siltstone clasts (12 percent) are rounded, well indurated and hematized, but not intraformational. The relatively high proportion of siltstone clasts, compared to that in stratigraphically lower conglomerates, is significant particularly as Langford (1981) suggested an unconformity between the Beaverlodge Formation and the Gillies Channel Formation.

### Seaplane Base Formation

Two localities in the Seaplane Base conglomerates were sampled northeast of Uranium City (Fig. 1, localities 202 and 353). Locality 202 is stratigraphically lower than 353. The basement to the north and west is dominated by units 19 and 17 of Tremblay (1972). Clast composition at 202 is dominated by granite gneisses and quartz whereas that at 353 is dominated by granite gneisses and quartzites. All the siltstones at this locality were derived locally from erosion of semiconsolidated silt beds in the Seaplane Base Formation. Clasts at locality 202 include basalts (mafics), which likely were derived from the Gillies Channel Formation. Similar basaltic clasts were also observed lower in the section at locality 176. At locality 353, higher in the section, no basalt clasts were encountered; their source area likely was covered by the accumulating sediments of the Seaplane Base Formation by this time.

### Taz Bay Formation

Taz Bay Formation clasts are derived from a highly complex basement. The basement at localities 310, 311 and 312 (Mazimhaka and Hendry, 1985, Fig. 3) consists of foliated granitic and amphibolitic to biotitic rocks (unit 1 of Koster, 1968), red granite gneisses (unit 2) and granite (unit 4). These units likely produced the clasts of granoblastic, foliated and granite gneisses at localities 310, 311 and 312. There are more granite gneiss clasts at locality 312 and in conglomerates cropping out to the southeast along the bay and along the south shoreline of Laird Island.

### Tazin Lake

At locality 299 (Mazimhaka and Hendry, 1985, Fig. 3) and along the eastern shore of Tazin Lake, clast types include granite gneisses, foliated gneisses and schists. Schists with large garnets up to 6 cm across constitute 30 percent of the clasts at locality 299. They were likely derived from the White Lake Complex, parts of which were described as "grey garnetiferous quartzofeldspathic gneiss, quartzite, amphibolite and mylonite" (unit 8 of Koster, 1970). Basement rocks east of Tazin lake are dominated by hematized retrograde metamorphic rocks (unit 9). Small outcrops of the White Lake Complex (unit 8) occur farther to the east but are extensive southeast of this area. The Taz Bay rocks around Olson and Taz Bays are commonly faulted against Thluicho Group sandstones. Only one sandstone clast was observed in the Taz Bay conglomerates east of Tazin Lake, so if the Thluicho Group was eroded to provide some of the detritus for the Taz Bay formation, very little of the debris has been preserved.

At localities north of Barber Point (Mazimhaka and Hendry, 1985, Fig. 3), the conglomerates immediately above the unconformity contain clasts of porphyroblastic granite and amphibolitic gneisses, and finer mafic rocks. Higher up in the sequence, clasts comprise well-rounded granitic and quartz pebbles and cobbles. The basement in this area consists of granites and granodiorites (unit 8 of Koster, 1968). There are sufficient variations within the migmatite and the granodiorite series of Koster (1968) to account for all the clasts in the Martin Group conglomerates in this area. Conglomerate composition varies from locality to locality according to local variations in basement composition.

### General Islands

Proportions of rock types recorded at three localities on Gravel Islands (Table 1) are highly variable among the three main components of granite gneiss, quartz and sandstone. Granite gneiss clasts increase from 9 percent at locality 74b, which is the lowermost in the sequence, to 49 percent of the recorded clasts at locality 421, the highest in the sequence. Quartz content decreases from 50 percent at locality 74b to 17 percent of recorded clasts at locality 421. Sedimentary rock clasts range from 24 to 39 percent of recorded clasts. The Gravel Islands Formation is cut by the Black Bay Fault to the east. On the east side of the fault rocks of the Jug Bay Formation are exposed, and farther to the east there are granite gneisses, quartzites, amphibolite, biotite schists and a variety of chloritic rocks in the exposed basement (Christie, 1948; Sibbald and Lewry, 1980). As suggested earlier by Langford (1981), clasts in this formation were likely derived from the Jug Bay Formation and the basement to the northeast of this area.

## Sediment Dispersal in the Martin Lake Basin

Palaeocurrent analyses by Tremblay (1972) were based on cross-bedding in the Lower Arkose Member (equivalent to the upper part of the Beaverlodge Formation and the sandstone of the Gillies Channel Formation in this report), and in the Upper Arkose Member (equivalent to the Seaplane Base Formation of this report). Tremblay's measurements revealed dispersal patterns with modes to the south-southeast, southwest and west-southwest in the Lower Arkose, and to the southeast and west-northwest in the Upper Arkose. Macey (1973) analysed data from the same two stratigraphic units as Tremblay and inferred a similar dispersal pattern to that of Tremblay. Both studies (Tremblay, 1972; Macey, 1973) provided paleocurrent directions which were highly variable.

Paleocurrent data in this study are based on measurements taken from the Gillies Channel Formation and the Seaplane Base Formation. All data were corrected for tectonic deformation by rotating the beds about the local strike. The most

abundant indicators are trough and planar cross-bedding in the sandstones and gravelly sandstone, but imbrication and alignment of conglomerate clasts proved useful too. Paleocurrent patterns are broadly similar to those interpreted by Tremblay (1972) and Macey (1973) and confirm the patterns inferred by Mazimhaka and Hendry (1984).

Flow directions in the Gillies Channel Formation were mainly to the southwest (Fig. 2). Directions for trough cross-bedding were based on inferred orientation of the trough axes at each locality. Variability is low. For example, at locality 174 (Fig. 1), flow directions inferred from planar cross-beds, trough cross-beds and imbrication range from 185° to 225°. Flow directions inferred from cross-beds in sandstones ranging from pebbly to fine grained, and with mean bed thickness of 20 cm, range from 210° to 225° (Fig. 2). The same low variability in flow direction in the Gillies Channel is observed in different areas and at different stratigraphic levels in the formation.

In the rocks of the Seaplane Base Formation, inferred paleocurrent directions are highly variable (Fig. 3), partly because current directions changed through time as the great thickness of sediments in the Seaplane Base was deposited, and partly because there were local variations in flow direction as a result of bar migration and changes of flow stage in the streams. Sections 176 and 5 add up to a section 1250 m thick (Mazimhaka and Hendry, 1984), and changes in flow directions inferred from planar cross-beds and trough cross-beds at localities 176, 5-11, and 5-10 (Fig. 3) in this section show variability through time. For example, in the lower 200 m of the section, inferred flow directions from axes of trough cross-beds are west-southwest and east-northeast (Fig. 3a); 800 to 900 m from the base of the section flow was to the northwest and southwest, and 1020 to 1100 m from the base of the section flow was south-southwest and southeast (Fig. 3b and c). The variability does not appear to be systematic.

Changes in flow direction resulting from bar migration and changes in flow stage in the stream may be observed in sections several metres thick. Inferred flow directions from planar cross-beds and trough axes in pebbly to medium-grained sandstones show high variability. At locality 5-11, variability is 75° in one set and 145° in another set. Trough cross-beds axes in the same section showed a small variation (070° to 076°).

Plunge of long axes of clasts at locality 202 (Fig. 3e) are west-northwest, southwest and southeast. On the basis of field evidence long axes of most clasts were oriented transversely to flow direction. Flow direction inferred from imbrication of clasts was west-southwest (Fig. 3f).

There are no structures on which to base a reconstruction of dispersal patterns in the Melville

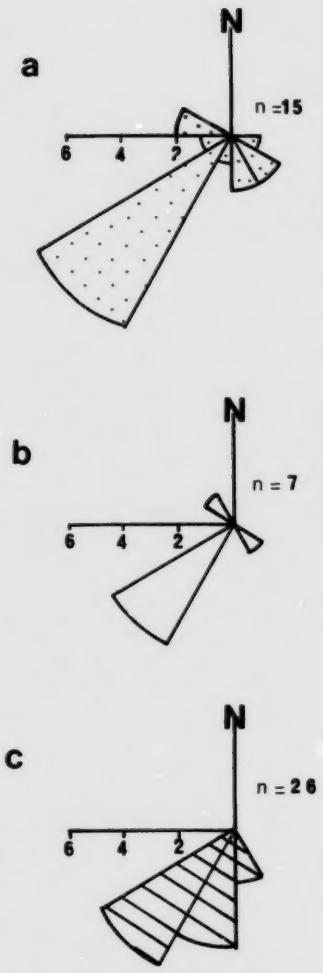


Figure 2 - Orientation of directional structures in the Gillies Channel Formation. Numbers refer to number of observations. a, direction of dip of planar cross-beds; b, axes of sets of trough cross-beds; c, imbrication of clasts.

Lake Formation. The abundant ripple marks were produced by waves and give no more than an indication of paleowind trends.

Sediment dispersal can be inferred also from a study of the distribution of sedimentary facies in the basin. Conglomerates in the Beaverlodge Formation were transported to the southeast, south and southwest from steep fault scarps (Mazimhaka and Hendry, 1984). In the Seaplane Base Formation the principal facies change from conglomerate to sandstone is from north to south.

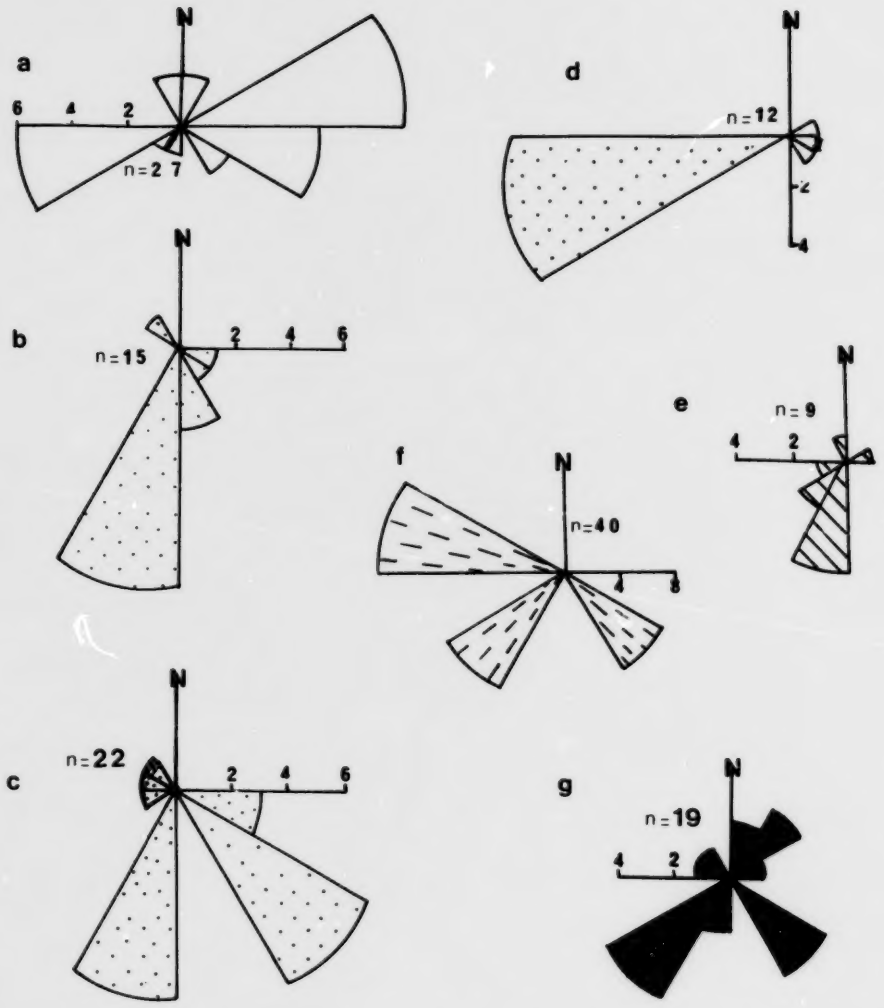


Figure 3 - Orientation of directional structures in the Seaplane Base Formation. Numbers refer to number of observations. a, axes of sets of trough cross-beds, locality 176; b, direction of dip of planar cross-beds, locality 5-11; c, direction of dip of planar cross-beds, locality 5-10; d, direction of dip of planar cross-beds, locality 202; e, imbrication of clasts, locality 202; f, plunge of long axes of clasts (long axes) locality 202, g, direction of dip of foresets of ripple marks, locality 182.

## Conclusions

1) Clast compositions in the Martin Lake and Tazin Lake basins indicate a main sediment source from basement immediately underlying the formations or in adjacent fault blocks.

2) Clasts in the Gravel Islands Formation were likely derived from the Jug Bay Formation and the basement to the northeast, as suggested by Langford (1981).

3) Conglomerate clasts in the Charlot Point Formation were mainly derived from sedimentary sources. The wide variety of clast types in the formation suggests that there were several sedimentary sources, including some of the Martin Group, the Thluicho Group and the Ellis Bay Formation.

4) Paleocurrent measurements in the Gillies Channel Formation show low variability and an inferred flow direction to the south-southwest. In the Seaplane Base, variability in the inferred flow directions is very high and results from variation in current direction through time as the sediment accumulated in the basin and locally as a result of bar migration and change in flow stage.

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Project 8605

# Mineralized Core Collection

by A.J. Gracie

Gracie, A.J. (1986): Mineralized core collection; in Summary of Investigations 1986, Saskatchewan Geological Survey, Saskatchewan Energy and Mines, Miscellaneous Report 86-4.

The Mineralized Core Collection has been previously described (Gracie, 1984) and an index to the collection released as an open file publication (Gracie and Gray, 1985). The index identifies the location of all core from drill holes by latitude and longitude and on 1:250,000 scale maps, and gives full particulars of each hole (company, mineral disposition, exploration commodity, year, hole number, core size, hole bearing and inclination, length of sample, reference to other available exploration data and storage location).

Activity funded under the Saskatchewan component of the Canada-Saskatchewan Subsidiary Agreement on Mineral Development 1984-89.

The collection is housed in the Precambrian Geological Laboratory in La Ronge. Contributions to the mineralized core collection totalled some 3641 m in 1986 (Table 1). Eighty-five persons examined core from the collection and ten persons resampled core from fourteen separate properties for new analyses. The mineralized core collection is augmented by an extensive collection of rock samples from mineral prospects in northern Saskatchewan. A catalogue of this sample collection is currently in preparation.

In addition to mineralized core, 1947 m of stratigraphic core (Table 2) were collected from the Athabasca Basin as a record of the Athabasca Group and 2262 m, already in storage, shipped to the Subsurface Geological Laboratory in Regina.

Table 1 - Core Acquisitions: September 1, 1985 to August 31, 1986

| Company or Joint Venture Operator (Commodity) | NTS Area | No. of Holes | Core Size | Property/Deposit Location by Lake | Meterage (m) |
|---|---|---|---|---|---|
| Amok Ltd./Ltée (U) | 74K-5-SE | 5 | BQ | ML 5186 Cluff Lake | 396 |
| Cogema Canada Ltd. (U) | 74I-1-SW | 1 | BQ | ML 5463 Waterbury Lake | 433 |
| E & B Explorations Ltd. (U) | 74I-6-NW | - | NB, BQ | MPP 1031 Pasfield Lake | 967 (12 m missing) |
| Eldorado Resources Ltd. (U) | 74N-7-SW | 1 | BQ | ML 5032 Stewart Island | 14 |
| Eldorado Resources Ltd. (U) | 74O-6-SE | 6 | AQ | ML 5251 Fond-du-Lac showing | 244 (missing core not determined) |
| Flin FLon Mines Ltd. (Au) | 63K-12-NW | 3 | NQ | ML 5106 Douglas Lake Core showing | 56 (26 m missing in two holes) |
| Flin Flon Mines Ltd. (Au) | 63K-12-NW | 3 | AQ | ML 5087 Bootleg Lake Rio zone | 222 (46 m missing in 3 holes) |
| Golden Eagle Oil and Gas Ltd. (U) | 64L-11-SW | 3 | BQ | CBS 5166 'Boulder' Lake | 473 |
| Noranda Exploration Company Ltd. (Au) | 73P-6-SE | 1 | NQ | CBS 7244 Ore Bay | 135 |
| Saskatchewan Mining Development Corp. (U) | 74I-14-NE | 1 | BQ | MPP 1087 Umfreville Lake | 333 (37 m missing) |
| Starrex Mining Corp. (Au) | 73P-16-NW | 1 | NQ | ML 5118 Star Lake 21 Zone Mine | 95 |
| Urangesellschaft (U) | 74I-9-NE | 1 | BNQ | MPP 1075 Kernaghan Lake | 214 |

Table 2 - Athabasca Group Stratigraphic Cores Shipped to the Subsurface Geological Laboratory, Regina, September 1, 1985 to August 31, 1986

| Company or Joint Venture Operator | NTS Area | No. of Holes | Core Size | Property Deposit | Meterage (m) |
|---|---|---|---|---|---|
| Cogema Canada Ltd. | 74I-1 | 1 | BQ | ML 5463 Waterbury Lake | 433 |
| E & B Explorations Ltd. | 74I-6-NW | 1 | NQ, BQ | MPP 1031 Pasfield Lake | 967 |
| Home Oil Ltd. | 74F-9-NW | 1 | NQ | MPP 1022 'Scurry' Lake | 576 |
| Marline Oil Corp. Ltd. | 74F-13-NE | 1 | NQ | CBS 5192 Shiels Lake | 472 |
| Marline Oil Corp. Ltd. | 74K-4-SE | 1 | NQ | CBS 1058 Shiels Lake | 494 |
| Saskatchewan Mining Development Corp. | 74I-14-NE | 1 | BQ | MPP 1087 Umfreville Lake | 333 |
| Seru Nucléaire (Canada) Ltée. | 74J-1-NW | 3 | NQ | MPP 1102 Rotariu Lake | approx. 720 |
| Urangesellschaft/U | 74I-9-NE | 1 | BQ | MPP 1075 Kernaghan Lake | 214 |

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Gracie, A.J. (1985): Mineralized Core Collection; in Summary of Investigations 1985, Sask. Geol. Surv., Misc. Rep. 85-4, p82.

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Project 8614

# Kisseynew Metallogeny: The Geology of the Schotts Lake Base Metal Deposit and the Dolly Gold Occurrence

by J.G. Pearson

Pearson, J.G. (1986): Kisseynew metallogeny: the geology of the Schotts Lake base metal deposit and the Dolly gold occurrence; in Summary of Investigations 1986, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 86-4.

The Kisseynew Domain in Saskatchewan hosts several as yet uneconomic base and precious metal deposits. In Manitoba, the late Sherridon Mine and recent exploration successes at Puffy Lake, Tartan Lake and Vamp Lake indicate host rocks in the Kisseynew Domain and in the Flin Flon/Kisseynew Domain transition as favourable for both base and precious metal mineralization. The objective of the present project is to evaluate the geology of the several Saskatchewan deposits. In this, the first year of the program, two deposits were examined: the Schotts Lake (copper-zinc) deposit and the Dolly (gold) occurrence.

## Schotts Lake Deposit

The Schotts Lake deposit, located 43 km northwest of Creighton, was first discoverd by prospectors in 1953. Since that time it has undergone several phases of investigation (geophysics and diamond-drilling). Current reserves are estimated to be 1,983,850 t (2,186,050 tons) grading 0.61 percent copper and 1.35 percent zinc (Assessment File[1] 63M01-0019).

### General Geology

The deposit lies on a peninsula in Schotts Lake within a group of volcanic and volcaniclastic rocks, which include hornblende-plagioclase gneisses (mafic volcanics), plagioclase-amphibole gneisses (intermediate volcanics or volcaniclastics), quartz-feldspar-biotite gneisses (metapsammites), quartzofeldspathic gneisses (meta-arkoses), calc-silicates, poikiloblastic hornblende-plagioclase-quartz gneisses (alteration zone?), quartz-feldspar-garnet-biotite gneisses (metapelites) and quartz-feldspar-magnetite gneisses (iron formation). These rocks are folded into a major synform with a moderately easterly-dipping axial plane.

[1]Saskatchewan Energy and Mines, Regina.

Project funded under the Saskatchewan component of the Canada-Saskatchewan Subsidiary Agreement on Mineral Development 1984-89.

### Description of Rock Types

Hornblende-plagioclase gneisses, interpreted to be mafic volcanics, outcrop along the east, south and southwest edges of the peninsula. Commonly they weather to a deep rusty red; however, where disseminated sulphides are present, they are light red. The fresh rock is black to dark green and is generally layered. Layering is marked by relative concentrations of plagioclase, garnet and less commonly calc-silicate minerals (diopside and epidote, often in association with disseminated sulphides). The irregular lensy distribution of garnet in some outcrops lends some of these rocks the appearance of coarse fragmentals. Rarely, thin units of very fine grained, massive quartz-feldspar-biotite-garnet gneiss and feldspathic quartzite are interlayered with the hornblende-plagioclase gneisses.

On a larger scale, feldspar-amphibole±garnet± biotite gneisses transitional into quartz-feldspar-biotite gneisses are also interlayered with hornblende-plagioclase gneisses. They contain 10 to 30 percent amphibole (commonly hornblende, except in the western part of the area where cummingtonite is dominant; anthophyllite is an uncommon accessory), 40 to 60 percent plagioclase, up to 20 percent quartz, 2 to 10 percent biotite and up to 5 percent garnet. These rocks often appear altered, yellow or reddish, and greasy.

The quartz-feldspar-biotite gneisses are grey to light brown and contain 30 to 60 percent quartz, 30 percent plagioclase, 15 to 25 percent biotite, minor hornblende (<5 percent) and garnet, and rare sillimanite. Compositionally they are semipelitic on average. They are in turn gradational into and interbedded with quartzofeldspathic gneisses (meta-arkoses) and the feldspar-amphibole gneisses.

A unit of quartz-feldspar-biotite-sillimanite gneisses is present along the eastern part of the mapped area, typically in association with the poikiloblastic hornblende-plagioclase-quartz gneisses. It is not clear if this represents a distinct stratigraphic unit, or if it is series of lenses forming part of the alteration zone. Large garnets (>5 mm diameter) are a common accessory.

Calc-silicates occur in two settings: within the hornblende-plagioclase gneisses and feldspar-

amphibole gneisses as narrow unmappable units characterized by quartz (40 percent), plagioclase (40 percent), diopside (15 percent) and trace amounts of calcite, biotite, pyrrhotite and chalcopyrite; and as a distinct mappable unit north of and structurally underlying the surface projection of the massive sulphide zone. The latter unit comprises quartz (40 percent), feldspar (50 percent), diopside partially altered to actinolite (15 percent) and traces of calcite, sulphides and sphene.

The quartzofeldspathic gneisses (meta-arkoses), occupying the center of the peninsula, are light brown rocks containing 40 to 60 percent quartz, 40 to 50 percent feldspar, 0 to 15 percent biotite, and accessory garnet, muscovite and sulphides (up to 10 percent). They commonly weather orange-yellow because of the contained sulphides. Interlayered with the quartzofeldspathic gneisses are narrow bands of feldspathic quartzite and quartz-feldspar-garnet-biotite gneiss. The former are uncertainly of volcanic (rhyolite) or sedimentary origin.

To the east of and structurally overlying the quartzofeldspathic gneisses, are discordant lenses of poikiloblastic hornblende-plagioclase-quartz gneisses thought to be derived from the alteration zone. Poikiloblasts and aggregates of hornblende up to 4 cm long commonly make up 30 to 70 percent of the rock. They are set in a matrix containing 50 to 70 percent plagioclase, 20 to 40 percent quartz, 0 to 10 percent garnet, and rare cummingtonite and anthophyllite. The more mafic varieties of this rock, with from 60 to 70 percent hornblende, are distinguished with difficulty from the mafic volcanics but for the randomly oriented texture and the poikiloblastic nature of the amphiboles.

Quartz-feldspar-biotite-garnet gneisses, unrelated to those described previously and located in the north-central part of the area, are white to light grey and comprise plagioclase (30 to 40 percent), quartz (30 to 40 percent), biotite (30 percent) and garnet (5 to 10 percent). They are medium grained (1 to 3 mm), granoblastic textured and commonly contain porphyroblasts of feldspar (up to 10 mm) and garnet (up to 5 mm). Gneissosity, defined by biotite- and garnet-rich layers, is commonly irregularly contorted and cut by bands of discordant neosome.

Iron formation occurs in two facies, sulphide and oxide-silicate. Massive sulphides do not outcrop, but underlie a small valley filled with fragments of gossan. In the immediate area of this valley are narrow bands of quartz-amphibole-magnetite-feldspar$\pm$biotite$\pm$garnet rock which commonly contain disseminated pyrite and chalcopyrite. Also in the immediate area, layers of quartzite and quartzofeldspathic gneiss may contain up to 10 percent pyrite and rare chalcopyrite.

A 7 m wide sill of pink granite intrudes the hornblende-plagioclase gneisses on the southeast part of the peninsula. The granite is pink weathering and pink to grey when fresh, and contains 40 to 60 percent quartz, 20 to 30 percent feldspar and 5 to 10 percent biotite. Garnet poikiloblasts, which are up to 8 mm in diameter, and K-feldspar phenocrysts occur locally. Conformable sheets and lenses of coarse-grained 'granite pegmatite', containing crosscutting veins of white and rose quartz, are common throughout the eastern part of the peninsula.

### Structure

The outcrop pattern, minor folds and lineations indicate that the rocks have been folded into an inclined synform with an axial plane which dips moderately east and an axis that plunges moderately northeast. The massive sulphides lie on the abnormal limb of a parasitic Z-fold developed on the eastern limb of this major structure.

### Interpretation

The distribution of the various rock types and the location of the interpreted alteration zone (poikiloblastic hornblende-plagioclase-quartz gneisses, quartz-feldspar-biotite-garnet gneisses and quartz-feldspar-biotite-sillimanite gneisses), overlying the massive sulphide deposit which is in turn underlain by a small calc-silicate unit, indicates that this deposit is a typical exhalitive massive sulphide zone, similar to those described by Sangster (1972). The deposit was formed in close proximity to volcanic and volcaniclastic rocks, with the development of an underlying footwall alteration zone characterized by variable mineralogy and discordant relationships to other rock units. The massive sulphide deposit seems to contain some distal magnetite-bearing iron formation and is capped by a small calc-silicate unit. The deposit is now overturned and lies on the abnormal limb of a parasitic Z fold on the eastern limb of a major northeasterly-plunging synform.

## Dolly Gold Occurrence

The Dolly gold occurrence is located 35 km north of Creighton, in the East Arm of Mari Lake. It was discovered by W. Boehme in 1930 (J. Lorsong, pers. comm.). Since that time, there have been several phases of exploration, involving prospecting, stripping and trenching and two phases of diamond-drilling, one in 1945 and the latest in 1986.

### General Geology

The occurrence is marked by a slightly discordant gold-quartz vein hosted by Kisseynew Gneisses near their contact with a body of Kipahigan Granite (Macdonald, 1975). The Kisseynew Gneisses include psammitic gneisses, metaconglomerates,

meta-arkoses and feldspathic quartzites, and hornblende-plagioclase gneisses. These supracrustals are intruded by feldspar porphyritic gabbro, early granite, quartz veins and late undeformed pegmatites. The relationship of the supracrustals to the Kipahigan Granite is unclear. Adjacent to the Kipahigan Granite contact, in particular, they are cut by narrow shear zones.

### Description of Rock Types

Psammitic gneisses are the dominant rock type. They interfinger with and overlie both the metaconglomerates and hornblende plagioclase gneisses, and are gradational into meta-arkoses along the western edge of the area. The gneisses are commonly layered on a 2 cm to 1 m scale, and contain 60 to 70 percent quartz, 15 to 25 percent biotite and 10 to 15 percent plagioclase. Epidote and amphibole-rich layers are characteristic, as are thin 'granite pegmatite' sills which often form high ridges and comprise up to 70 percent of outcrops.

Metaconglomerates, which form a mappable unit in the west of the area, contain quartzofeldspathic, zoned, epidote-rich and uncommonly granitoid clasts up to 10 cm in maximum dimension. Clasts comprise from 5 to 25 percent of the rock. The pink and green epidote-rich clasts, which contain disseminated magnetite, are commonly zoned and show resistantly weathering cores. The clasts are typically deformed and those that are quartzofeldspathic have length:width ratios of up to 7:1. The matrix is of variable composition, but generally comprises quartz (20 to 30 percent), feldspar (50 to 60 percent) and biotite (10 to 20 percent). Epidote is abundant in some layers and hornblende in others. Magnetite is a common accessory. Compositional layering varies on a scale of 2 to 10 cm. Some layers, particularly those in areas with abundant epidote clasts, contain large hornblende crystals (up to 5 mm) in a plagioclase-rich matrix. Boudinaged quartz veins are common.

Hornblende-plagioclase gneisses interpreted to be mafic to intermediate flows or sills lie structurally below the metaconglomerates. They comprise 20 to 40 percent quartz, 10 to 20 percent plagioclase, 20 to 40 percent hornblende and up to 15 percent biotite. Disseminated pyrite, pyrrhotite and magnetite are common.

Meta-arkoses, gradational in composition from psammitic gneiss to feldspathic quartzite, are common along the western edge of the map area. They are white to grey, fine grained (<1 mm) and weakly compositionally layered. Accessory magnetite, up to 10 percent disseminated pyrite and yellow to red weathering (depending on sulphide content) are characteristic.

Feldspar porphyritic gabbro outcrops as a 6 m thick weakly discordant body in psammitic gneisses near their contact with the Kipahigan Granite. Plagioclase crystals, occurring as discrete 3 cm long individuals or in glomeroporphyritic clusters, make up to 40 percent of the rock. They are set in a fine-grained (0.5 mm) matrix of hornblende (60 percent), quartz (30 percent) and plagioclase (10 percent). The gabbro is variably sheared, typically in zones up to 1 m wide, both internally and along it's contacts with the surrounding gneisses. Where sheared, the feldspar crystals are extremely stretched and the rock has a gneissic appearance.

Three phases of granitic intrusion are identified. The earliest (the Dolly granite) outcrops along the baseline in proximity to the gold-quartz veins and crosscuts both the psammitic gneisses and the feldspar porphyritic gabbro. Where boudinaged within shear zones, it appears internally undeformed. The granite is pink on both fresh and weathered surfaces and comprises 35 percent quartz, 60 to 70 percent feldspar, 5 to 10 percent biotite, rare white mica and finely disseminated hematite. At one location the rock shows a gradation into and is interlayered with the gold-quartz vein.

The Kipahigan Granite, which underlies the eastern margin of the area, is pink on both fresh and weathered surfaces, medium to fine grained (<1.5 mm), and contains quartz (25 percent), feldspar (50 to 60 percent), biotite (10 to 15 percent) and minor muscovite. The contact with the surrounding supracrustals is sharp and apparently intrusive. To the north of the mapped area, however, a faulted contact was noted at one location. The granite contains several narrow (3 cm) barren quartz veins, narrow aplite dikes and rare rounded, partially assimilated xenoliths of fine-grained granodiorite.

Coarse-grained pink, undeformed 'granite pegmatite' sills intrude the psammitic gneisses in the area to the west of the gold-quartz veins.

### Structure

The supracrustal rocks form a moderately northeast-dipping homoclinal sequence. Boudinaged quartz veins and flattened pebbles are moderately east-northeast plunging.

Moderately northeast-dipping shear zones occur in proximity to the gold-quartz veins and in some cases follow lithologic contacts and in others lie within discrete rock units. In these zones a sinistral movement is generally apparent from displacement of crosscutting granite dykes.

However, in the middle stripped area at the showing, a small, somewhat discordant granitic to aplitic sill shows deformation features with conflicting movement sense (Fig. 1). Closely spaced crosscutting shear planes indicate sinistral movement, whereas S-shaped quartz veinlets which

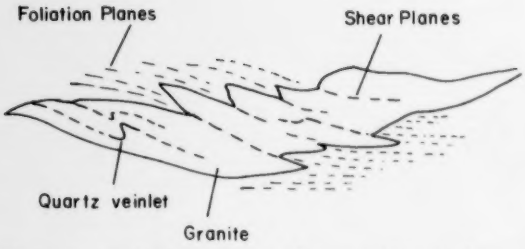


**Figure 1 - Faulted sill of granite or aplite showing crosscutting shear planes indicating sinistral movement and deformed quartz-filled tension gashes suggesting dextral movement.**

lie between and are strung out along the shear planes suggest dextral movement.

## Mineralization

The gold-quartz veins are essentially of white, glassy and massive quartz with associated rare blebs of pyrite, chalcopyrite, tourmaline and possibly molybdenite. In places, the quartz veins seem to be interlayered with and gradational into Dolly granite, which at one location contains tourmaline. Small folded veins in the feldspar porphyritic gabbro show comb texture, indicating open space filling. Gold values reported in assessment work (Assessment File 64N04-0002) range up to 17 ppm (0.5 oz./ton) Au over 1.83 m.

## Interpretation

Two observations appear to be significant in interpreting the origin of the gold quartz mineralization:

1) apparent textural similarities and gradational contacts between the early crosscutting granite bodies (Dolly Granite) and the gold quartz veins;
2) deformation fabrics in the quartz veins and supracrustal host rocks.

The textural similarities between the quartz veins and the Dolly granite and their apparent interfingering indicate that the quartz veins may be a phase of the Dolly granite. If this interpretation is correct, one could envisage that the Dolly granite might have elevated gold values. Recent channel sampling by Wapa Minerals appears to confirm this hypothesis (J. Lorsong, pers. comm.).

Deformation fabrics (folding and boudinage) indicate that the quartz veins were intruded as open-space fillings early in the strain history of the shear zones, which show a sinistral movement sense. Linear fabrics plunge at approximately 30° to the east-northeast. This indicates that the main gold-quartz vein, which on surface has an exposed strike length of 65 m, plunges in the same direction and may also be boudinaged.

## Acknowledgments

I wish to thank Stall Lake Mines Ltd. for access to the Schotts Lake property. I also wish to thank Wapa Minerals for access to the Dolly property, for their co-operation in providing the results of recent geological mapping and diamond-drill programs, and for discussions which gave additional insight into the geology.

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MINERAL DEVELOPMENT AGREEMENT PROGRAM (CANADA COMPONENT)

# Regional Reconnaissance Geochemical Lake Sediment and Water Surveys, North-Central Saskatchewan (Parts of NTS 74A, B, G and H)

by P.W.B. Friske[1]

Friske, P.W.B. (1986): Regional reconnaissance geochemical lake sediment and water surveys, north-central Saskatchewan (parts of NTS 74A, B, G and H); in Summary of Investigations 1986, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 86-4.

A regional lake sediment and water survey was carried out under contract by the Geological Survey of Canada over 17,000 km$^2$ of central Saskatchewan (Figure 1). The survey covered parts of NTS map areas 74A (Foster Lake), 74B (Mudjatik), 74G (Cree Lake) and 74H (Geikie River) south of the Athabasca Basin and contiguous with previous regional lake sediment surveys released as GSC Open Files 266, 556, 1106, 1129 and 1213. Samples were collected from a total of 1,270 sites for an average sample density of 1 site per 13 km$^2$.

Lake sediments will be analyzed for Zn, Cu, Pb, Ni, Co, Ag, Mn, Cd, As, Mo, Fe, V, Hg, U, Sb, Au and LOI. Lake waters will be analyzed for U, F and pH. Survey results will be released as GSC Open File 1359 in early summer, 1987, and will comprise sample location and value maps at 1:250,000 scale, sample value and site data, summary of statistical parameters, and surficial deposit and regional trend maps at 1:1,000,000 scale.

Sample collection in 1986 was carried out by SIAL Geophysique Inc. with helicopter services provided by Viking Helicopters Ltd. Sample preparation was performed by Golder Associates of Ottawa. Lake sediments will be analyzed by Barringer Magenta Limited in Toronto and Chemex Labs Ltd. in Vancouver (gold only). Water analyses will be performed by Barringer Magenta Laboratories (Alberta) in Calgary.

The survey area encompasses parts of the Precambrian Wollaston, Mudjatik and Virgin River Domains, and the Western Craton, which consist of amphibolite to granulite facies metamorphosed mafic to felsic intrusive and volcanic rocks, and mixed sedimentary rocks. In the northern part of the survey area, Athabasca Basin sedimentary rocks overlie Precambrian basement.

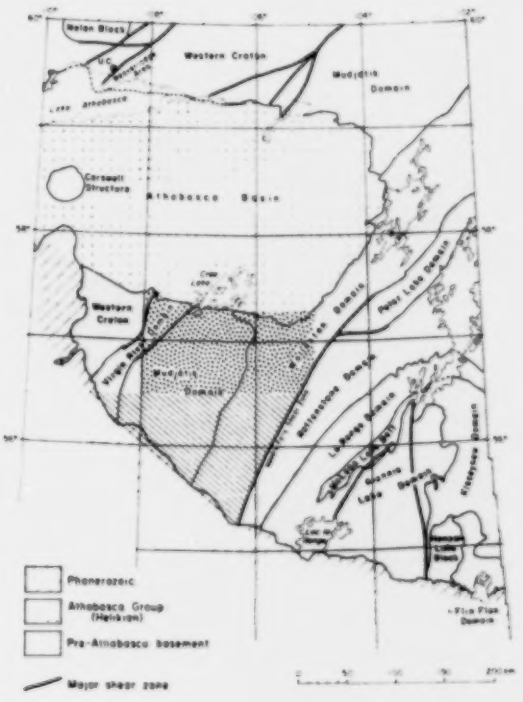



Figure 1 - National Geochemical Reconnaissance lake sediment and water surveys, Saskatchewan. Light dot pattern, pre-1985 survey area; striped pattern, 1985 survey released as Open File 1213 in June, 1986; bold dot pattern, 1986 survey area.

The 1986 survey completes regional lake sediment coverage of the southern and eastern shield areas of Saskatchewan. To date a total of 10,400 centre-lake sediments and 6,870 surface lake waters have been collected from nearly 131,000 km$^2$ of Saskatchewan.

[1]Exploration Geochemistry Subdivision, Geological Survey of Canada.

Project funded under the Canada component of the Canada-Saskatchewan Subsidiary Agreement on Mineral Development 1984-1989.

# Biogeochemical Studies in the Saskatchewan Gold Belt, 1986

by Colin E. Dunn[1]

Dunn, C.E. (1986): Biogeochemical studies in the Saskatchewan gold belt, 1986; in Summary of Investigations 1986, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 86-4.

Biogeochemical studies conducted in recent years have shown that chemical analyses of vegetation comprising Canada's northern forests can assist in delineating zones of gold mineralization (Dunn, 1984, 1985, 1986; Cohen et al., in press). Detailed surveys (50 m spacing) and those at reconnaissance levels (up to 2 km spacing) have both provided positive indications of mineralization. For surveys covering tens of square kilometres, a 200 m sample interval along traverses normal to the bedrock strike is a practical compromise between the accumulation of vast quantities of material at the 50 m detailed scale, and sampling at 2 km reconnaissance scale which may miss many zones of interest. Hence, for this study, samples were collected at intervals of 200 m within a 150 $km^2$ area (Fig. 1), referred to here as the "Star Lake" area, that includes the mineral occurrences between Neyrinck and Jojay Lakes. This survey constitutes part of an integrated biogeochemical/ remote sensing program, details of which are given in Dunn et al. (this volume)

The limits to sample collection in the Star Lake area were determined by ease of access from roads and trails; the distribution of bogs, lakes, and burn areas; and "down-time" due to bad weather. Four weeks (from late May) was considered the maximum period permissible for sample collection, because of seasonal variations in plant chemistry (Dunn 1984, 1985). If the survey had been extended for a longer period, data from samples collected at the start and finish of the survey period could not have been readily compared, as gold concentrations in some plant organs decrease through the growing season.

In theory, samples spaced at 200 m intervals for 10 km along 16 lines spaced 1000 m apart (normal to the bedrock strike) would provide 816 samples over the 150 $km^2$ area, giving a sample density of 5.4 per $km^2$. However, this does not take into account lakes, bogs and burnt areas; moreover, such a systematic coverage requires extensive air support. In practice, two teams of two persons were able to collect samples of two media per site and record appropriate geological and environmental notes from about 600 locations within the allotted time, thereby providing a coverage of 4 per $km^2$.

In addition, brief studies were made near zones of gold mineralization at Laonil and Puswawao Lakes, outside of the main study area.

[1]Resource Geophysics and Geochemistry Division, Geological Survey of Canada.

Studies in northern Saskatchewan have shown that, locally, twigs of alder (Alnus crispa) are enriched in gold near zones of gold mineralization (Dunn, 1984). Elsewhere, the outer bark scales of black spruce (Picea mariana) reflect more strongly the presence of mineralization (e.g., Waddy Lake; Dunn, 1985). Environment can play an important role in the distribution of elements among plant species, causing species other than alder and spruce to be more sensitive to gold under certain conditions. For example, prior to development of the Star Lake gold mine, labrador tea and leather leaf collected from the peat bog over the 21 Zone contained more gold than other species (Dunn, 1985).

The most common species in the Star Lake area are black spruce and alder. Hence, alder twigs and spruce bark scales were the principal media selected for this survey, plus spruce twigs from about 20 percent of the sample locations. The spruce bark is a particularly suitable medium in that it comprises dead material which is not subject to seasonal changes in chemistry. More useful information could probably be obtained from sampling additional media (e.g., labrador tea), but a reasonable limit had to be set on the scope of the study.

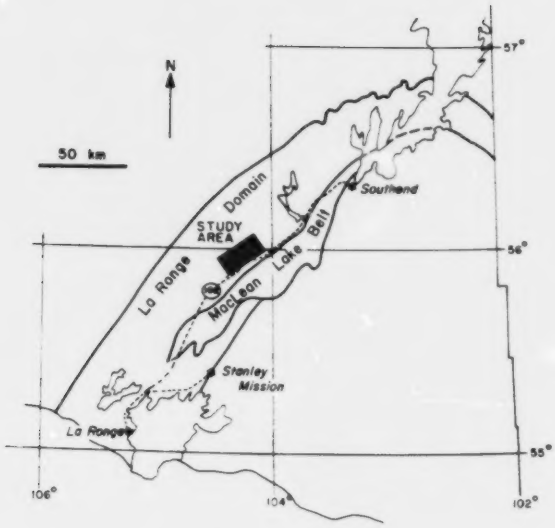
## Sample Collection, Preparation, and Analysis

Procedures for collecting, drying, separating, ashing and analysis (neutron activation) used in previous years were adopted for this survey (Dunn, 1984, 1985). A multi-element neutron activation package of Nuclear Activation Services Ltd. provided data on Ag, As, Au, Ba, Br, Ca, Co, Cr, Cs, Fe, Hf, Mo, Na, Ni, Rb, Sb, Sc, Se, Sr, Ta, Th, U, W, Zn, and the rare-earth elements La, Ce, Nd, Sm, Eu, Yb, Lu. Detection limits and background levels of these elements in alder twigs and spruce bark are given in Dunn (1985, Table 1).

Data presented in this report are concentrations in ash. Reasons for ashing samples rather than analyzing dried material are discussed in an earlier report (Dunn, 1985).

## Preliminary Data from the Main Survey Area

Analytical data for 32 elements in spruce bark have been received, and a preliminary evaluation made of the gold data. At many sites, gold concentrations are below the detection limit of 5 ppb and, in general, the geochemical data



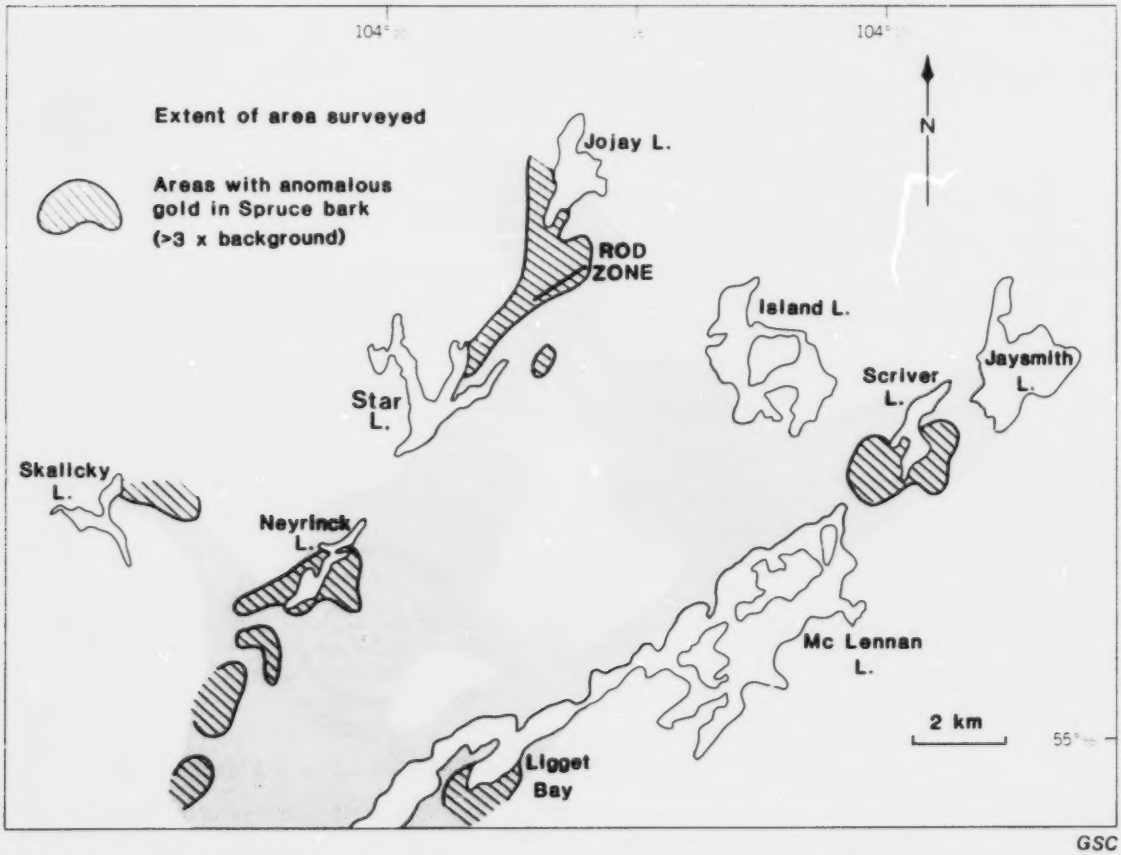




Figure 1 - Location map showing extent of area surveyed, and areas with gold in spruce bark greater than three times background.

exhibit low variability. Throughout the survey area the concentrations of gold in spruce bark ash are generally lower than those in the southern part of the La Ronge Domain (cf. Dunn, 1984, 1985). Whereas 10 to 15 ppb Au constitutes background concentrations to the south, similar levels obtained in the present survey are considered anomalous, because background is less than 5 ppb Au. This difference may be the result of a greater mobility of gold around the more southerly deposits, due to their chemical melting and the nature of the disseminated mineralization. Given this mobility, the plants are able to pick up and accumulate more gold. Gold deposits in the Star Lake region tend to be "cleaner" (i.e., native gold trapped in quartz veins, and with generally few associated trace metals). The resultant lower background levels need to be taken into account when evaluating biogeochemical data from the current survey area.

Some areas, however, do show multi-sample enrichment of gold (Fig. 1):

1) West and south Jojay Lake, notably in the area around the Rod Zone, where there is up to 690 ppb Au (see next section entitled "Rod Zone - Mallard Lake Area"), and 500 m southwest of Rush Lake with 380 ppb Au.

2. Around Neyrinck Lake (to 23 ppb Au) and for 4 km to the southwest, where several samples have yielded around 20 ppb Au and isolated values of 81 and 160 ppb Au.

3. Between Jaysmith and Scriver Lakes, numerous samples have fairly low (10 to 16 ppb Au) yet regionally anomalous (2 to 3 times background) gold concentrations. To the west of Scriver Lake, near the eastern edge of the Island Lake Pluton, gold levels are generally higher with up to 58 ppb Au.

4. Around Liggett Bay (central part of McLennan Lake), gold levels are slightly anomalous (10 to 17 ppb Au).

5. East of Skalicky Lake (northwest corner of survey area), values are similar to those at Liggett Bay.

Rod Zone - Mallard Lake Area

In September 1985, a traverse was made along the Rod Zone, northward from the main trenched occurrence that contains native gold and molybdenite in quartz veins. Since both outcrop and gold mineralization are sporadic along this shear zone, spruce bark and alder twigs were sampled in an attempt to identify auriferous sections. Table 1 shows the great variation in gold content of spruce bark along the transect. The strong response above the main trenched occurrence is repeated elsewhere, which suggests that mineralization is also located at sites 10+00N, 11+00N, and 13+00N.[1]

Table 1 - Gold Content (ppb) of Ashed Bark Scales from Black Spruce Along the Rod Zone.

| Cut-line Coordinate Along Baseline | Distance (m) Northeastward from Trench with Au and Mo | Gold (ppb) in Spruce Bark Ash |
|---|---|---|
| 6 + 50E | 0 | 230 |
| 9 + 50E | 300 | 24 |
| 10 + 00E | 350 | 120 |
| 10 + 50E | 400 | 23 |
| 11 + 00E | 450 | 690 |
| 11 + 50E | 500 | 40 |
| 12 + 00E | 550 | 6 |
| 12 + 50E | 600 | 55 |
| 13 + 00E | 650 | 450 |
| 13 + 50E | 700 | 10 |
| 14 + 00E | 750 | 10 |

No other element shows enrichment in the spruce bark. The alder twigs yielded one to three times background concentrations of gold along the traverse, and indicate local enrichment in Mo (61 ppm) and Co (28 ppm).

Subsequent exploration in this area by Mahogany Minerals has led to the discovery of gold mineralization (0.1 oz./ton Au) close to the site that gave 600 ppb Au in the bark, and a probable economic deposit (0.5 oz./ton Au) has been found less than 50 m from the site with 450 ppb Au in spruce bark (G. Burrill, pers. comm.). Farther south, about 150 m from the main trench, drilling has intersected mineralization with locally over 1.0 oz./ton Au at a location which had previously yielded 200 ppb Au in bark. Clearly the amount of gold in the vegetation is not proportional to the grade of gold mineralization, but this is to be expected unless all the mineralization is at bedrock surface. The deeper the mineralized body occurs, the more dissipated the geochemical signature becomes. The important point is that anomalous biogeochemical values (whether high or low in magnitude) can be evidence of local mineralization.

Laonil Lake - Seabee Gold Property (NTS 63M/12)

A brief visit was made to the Laonil Lake area to collect vegetation from the vicinity of the V8 Shear Zone. The purpose was to establish the trace element uptake of several species in this geological

[1]The sample containing 690 ppb Au has been returned from neutron activation analysis and analyzed by a wet chemical method in laboratories of the Geological Survey of Canada, Ottawa. The analyst was not informed of the NAA value, yet returned a comparable assay of 687 ppb Au (G. Hall and J. Vaire, pers. comm.).

environment, and subsequently assess the potential usefulness of the biogeochemical method in assisting exploration in this area.

Mineralized zones occur in sheared gabbroic rocks cut by quartz veins and stockworks. Tourmaline occurs in the veins and wall rock, and the quartz contains gold, pyrrhotite, pyrite and rare chalcopyrite. Details of the geology are given in Lewry (1977) and Delaney (this volume).

Thirty-eight samples were collected from 18 sites (Fig. 2) across and along the V2 Zone, which forms a well-drained northwesterly-facing ridge. The most common species is black spruce; hence spruce bark scales were obtained at all sample sites, and spruce twigs from the twelve sites where the branches were within arms reach. In addition, samples of alder twigs, birch twigs, and jack pine bark were taken from the few places where they were growing near the spruce sample locations.

Figure 2 shows strongly anomalous gold concentrations (45 to 330 ppb Au) in spruce bark ash from six locations, with anomalies of lesser magnitude (22 to 26 ppb Au) from three more. It is noteworthy that the highest value is similar to values recorded from spruce bark at several sites near the Komis deposit at Waddy Lake (Dunn, 1985). It appears that background values for the Seabee area are less than 10 ppb Au in the bark. Gold in spruce twig ash ranges from 2 to 750 ppb

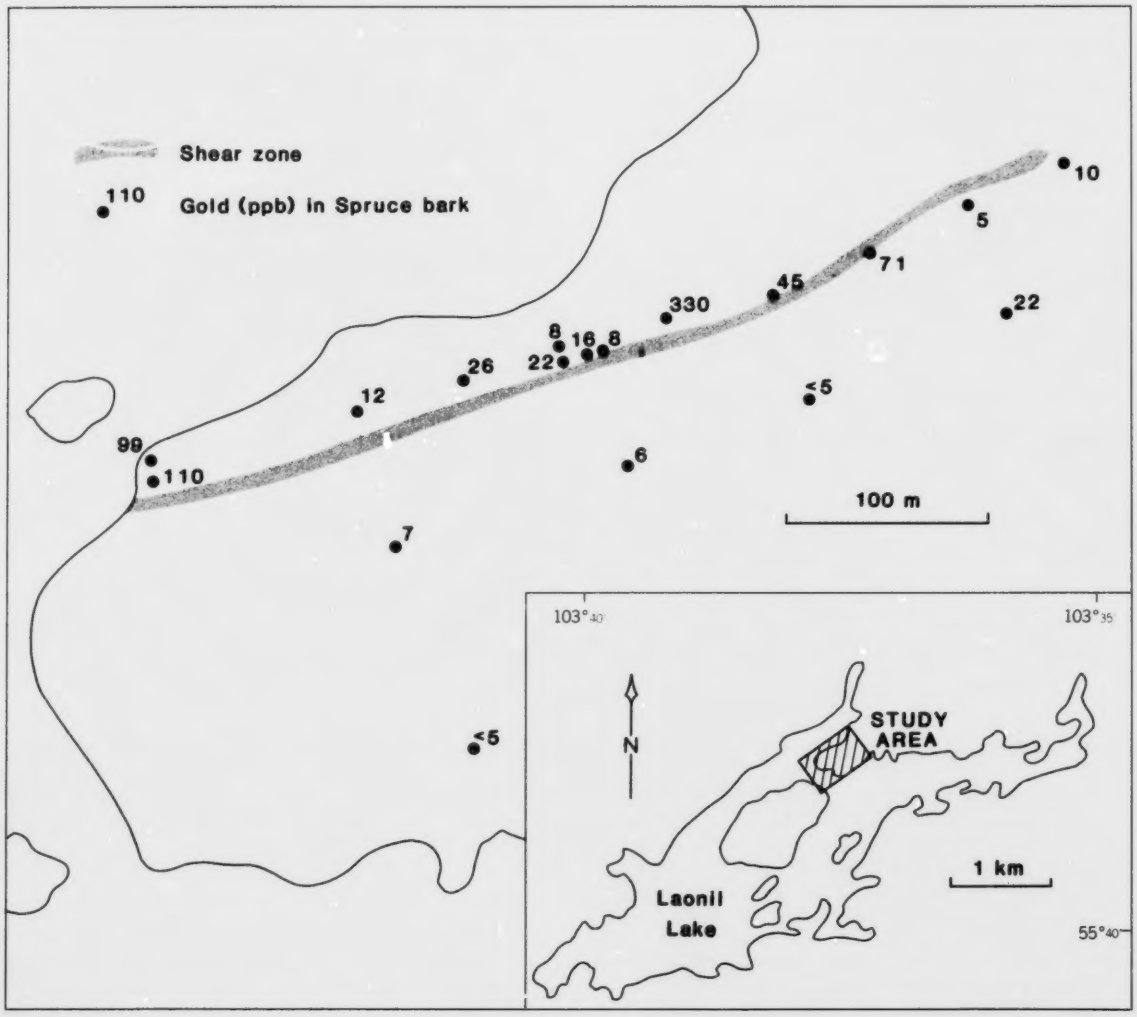



Figure 2 - Gold (ppb) in ashed spruce bark, Laonil Lake - Seabee Property.

Au, with the maximum concentration from a tree adjacent to that which yielded 330 ppb Au in its bark (Table 2).

Table 2 - Laonil Lake (V2 Zone) - Comparison of Gold Content (ppb) of Ashed Vegetation (see Fig. 2 for locations).

| Site No. | Black Spruce Bark | Black Spruce Twigs | Alder Twigs | Jack Birch Twigs | Pine Twigs |
|---|---|---|---|---|---|
| 1 | 110 | - | - | - | - |
| 2 | 99 | 37 | 6 | 34 | - |
| 3 | 12 | 6 | - | - | - |
| 4 | 26 | 17 | - | - | - |
| 5 | 8 | 8 | - | - | - |
| 6 | 22 | - | - | - | - |
| 7 | 16 | - | - | - | - |
| 8 | 8 | - | - | - | - |
| 9 | 330 | 750 | - | 64 | - |
| 10 | 45 | 30 | - | - | - |
| 11 | 71 | 17 | - | - | - |
| 12 | 5 | - | - | - | - |
| 13 | 10 | - | - | - | - |
| 14 | 22 | 9 | 11 | 34 | 8 |
| 15 | <5 | 5 | - | - | - |
| 16 | 6 | 8 | - | - | - |
| 17 | 7 | 15 | - | - | - |
| 18 | <5 | 12 | 9 | - | 11 |

Arsenic (up to 12 ppm) is commonly above the usual background levels (2 to 4 ppm) for spruce bark, but cannot be considered highly indicative of mineralization, since above-background concentrations are quite common throughout the Saskatchewan gold belt.

Data from several thousand samples in Saskatchewan show that tungsten is rarely above the 1 ppm detection limit of the analytical method. Three spruce bark samples from near the V2 Zone yielded 6, 3 and 3 ppm W, suggesting some tungsten enrichment in the bedrock.

A preliminary assessment of REE data from spruce bark suggests an unusual enrichment of neodymium, with respect to lanthanum and cerium concentrations. Whereas background levels are usually less than 5 ppm Nd, several samples with only 3 to 5 ppb Au have over 10 ppm Nd. Thus it appears that there is an imbalance of some REE concentrations, the significance of which is unknown.

Other elements are locally concentrated in some species:

1) Molybdenum up to 430 ppm (background usually 1 to 5 ppm) in alder twigs (cf. 11ppm Mo at Star Lake); 34 ppm Mo around the Rod Zone; and up to 230 ppm Mo at Waddy Lake;

2) Cobalt up to 66 ppm (background usually less than 10 ppm) in birch twigs (cf. dwarf birch twigs from close to the Lupin gold mine (NWT), 62 ppm Co; from the Tundra gold mine (NWT), 33 ppm Co; and the Star Lake gold mine, 32 ppm Co). Alder twigs (similar background values to birch) contain up to 66 ppm Co above the decline at Mallard Lake, and 28 ppm Co along the Rod Zone. Molybdenite and cobalt-bearing minerals have been reported from several of these gold deposits.

In summary, the vegetation indicates that, near mineralized veins in the Laonil Lake area, there are enrichments of Au, Co, Mo and W, with possibly some chemical differentiation of the rare-earth elements. Slight enrichments of As and Cr are noted. Multi-element biogeochemical surveys in this area may assist in outlining mineralized zones, and could help in differentiating between auriferous and barren shear zones.

Puswawao Lake (NTS 74A/1)

In light of information supplied by the Saskatchewan Mining Development Corporation (SMDC) from encouraging drillhole intersects of gold and base metal mineralization near Puswawao Lake, and earlier reports of gold traces in that area (Miller, 1949), a visit was made to this locality (4 km west-northwest of Windrum Lake, Fig. 3) to test the vegetation response to mineralization.

The topography consists of low hills and ridges with dry woodland separating boggy depressions. Only one outcrop, identified as a felsic metavolcanic, was encountered on the 3 km traverse to collect vegetation. The area has been mapped as meta-andesite and metadacite, cut by a shear zone containing white quartz-sericite schist that has yielded traces of gold and silver (Miller, 1949; Beck, 1959). The shear zone may be an extension of that which transects Jojay lake to the south (Miller, 1949). Pyrite is present, and a green chrome-mica, typical of that commonly found with gold mineralization, has been observed (SMDC, pers. comm.).

Spruce bark samples were obtained from 21 locations, and alder twigs from seven of these. Data received from the bark samples show unusually strong enrichment of gold (1300 ppb) at one site, and above background concentrations at five others (Fig. 3).

Moderate arsenic enrichment is present (up to 17 ppm As or about 5 times background), with locally anomalous levels of antimony (6 ppm Sb or 5 times background), cobalt (23 ppm Co or 3 times background), chromium (46 ppm Cr or 3 times

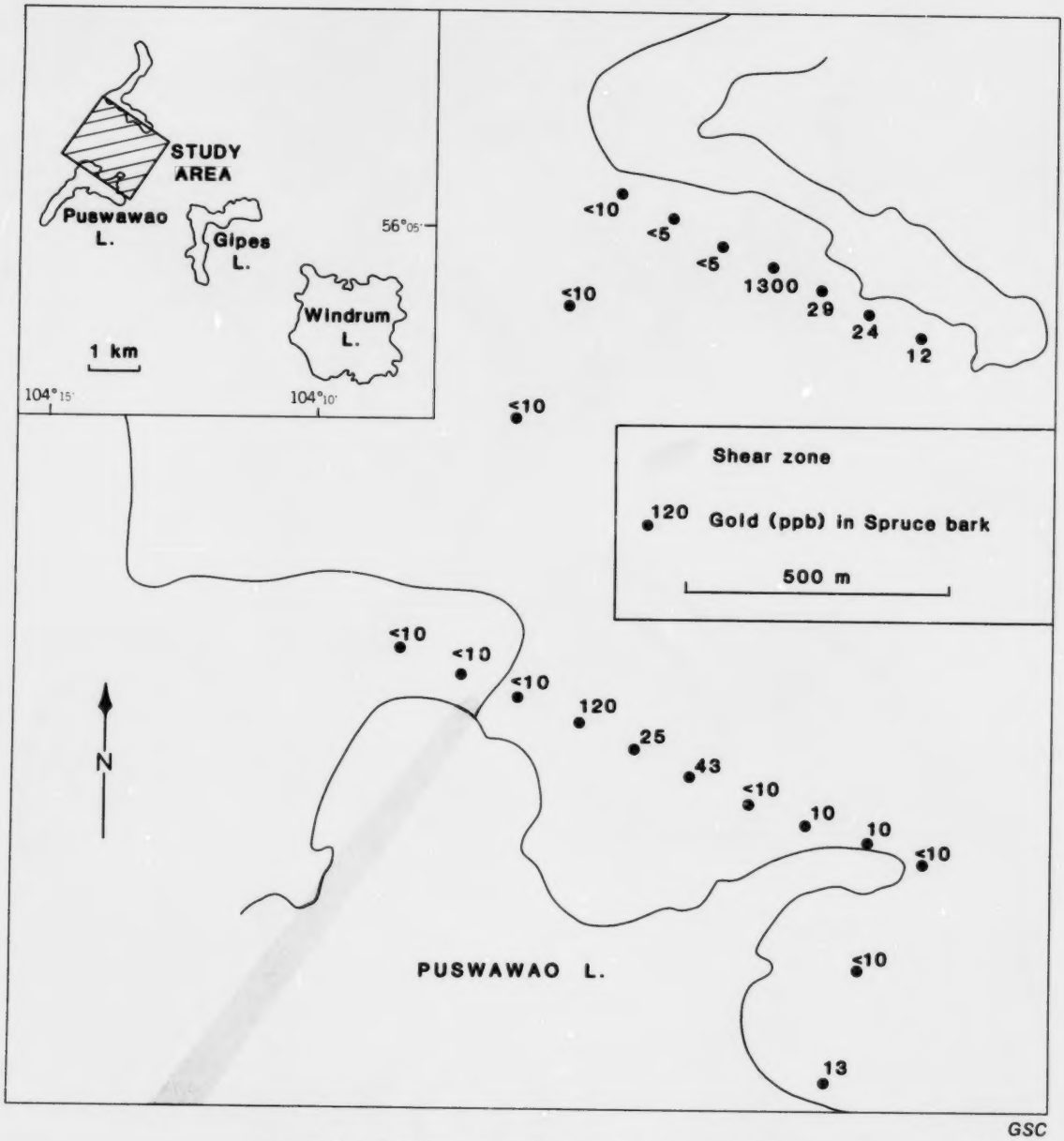



Figure 3 - Gold (ppb) in ashed spruce bark, Puswawao Lake.

background), cesium (6 ppm Cs or 3 times background), rubidium (360 ppm Rb or 5 times background), thorium (6 ppm Th or 3 times background) and possibly selenium. Preliminary data indicate 18 ppm Se which, if verified, is at least ten times background.

These biogeochemical data indicate the presence of mineralization in this area.

Acknowledgments

I thank the many property owners on whose land we have worked this summer, for the various pieces of information supplied and for their cooperation whenever requested. In particular I am grateful to the Saskatchewan Geological Survey for the loan of two assistants (D. Toop and D. Dyck) for part of the field season, and for the generous use of the laboratory facilities in Regina.

T. Kotzer, N. Richmond and R. Banville are the assistants who really deserve all the credit for the successful completion of this field season, to them I extend my gratitude for all their troubles.

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# Integrated Biogeochemical and Remote Sensing Studies, Star Lake Area, Saskatchewan

by Colin E. Dunn[1], A. Rencz[1], G. Bonham-Carter[1] and J.R. Belanger[1]

Dunn, C.E., Rencz, A., Bonham-Carter, G. and Belanger, J.R. (1986): Integrated biogeochemical and remote sensing studies, Star Lake area, Saskatchewn (NTS 73P-16 and 74A-1): in Summary of Investigations 1986, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 86-4.

Remote sensing techniques are proven methods for identifying zones of mineralization in many parts of the world. Relative changes in the spectral reflectance of healthy and stressed vegetation can be measured by airborne sensors, and the digital data obtained can be mathematically processed and displayed, for example, on a computer screen as a false colour map. With regard to mineral exploration, these techniques rely upon elements associated with mineral bodies becoming concentrated in plant tissues and creating measurable stress in the plants. There is an urgent need for "ground-truth" data (especially chemical analysis of plants) to help understand the patterns observed from remote sensing studies.

## Choice of Test Site

Preferred conditions for establishing a suitable test site are: 1) an area of known mineralization with good potential for the discovery of more mineralization (an active area of gold exploration was appropriate to try and address the current needs of the mining community); 2) a forested area with fairly even distribution of species; 3) an area that has been little disturbed by man; 4) an area of varied geology, in order that the biogeochemical and remote sensing methods might help differentiate lithologies; and 5) an area for which a comprehensive recently mapped geoscience database is available.

A location which fits these requirements is that around Star Lake in the La Ronge gold belt. This choice of test site was prompted by current interest in the area, which has resulted in the discovery of several zones of gold mineralization, and the excellent geoscience database which is steadily accumulating through activities under the current federal-provincial agreement (e.g. Thomas, 1984, 1985; Poulsen et al., 1985, 1986).

Figure 1 shows the area (approximately 150 km$^2$) under consideration, which is located entirely in the La Ronge Domain and extends from the metasediments of the McLennan Group in the southeast, across the McLennan Lake Tectonic Zone, and into the metavolcanics and plutons of the Central Metavolcanic Belt which contain most of the known gold occurrences of the region. Metasediments of the Crew Lake Belt occur to the northwest of another shear zone.

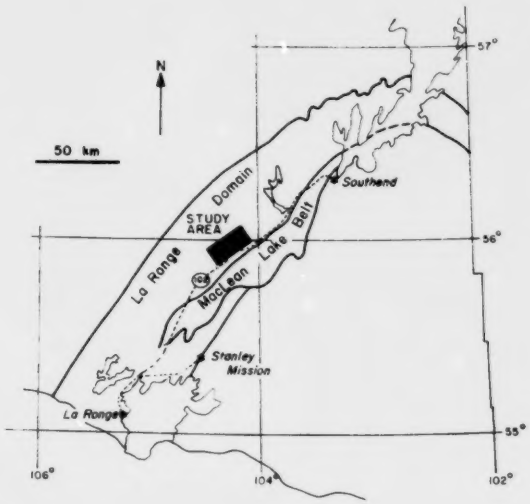


Figure 1 - Location of survey area

## Outline of Study

The components of the study area:

1) **Biogeochemistry:** Regional sampling of spruce bark scales and alder twigs at 200 m stations along traverses practical to conduct from roads and trails. Local detailed sampling (50 m spacing) in a few areas. The choice of sample medium was guided by experience gained throughout the La Ronge Domain over the previous two years (Dunn, 1984, 1985).

   Status: Samples were collected from over 600 sites during May and June, 1986. Most samples have been prepared for neutron activation analysis, and multi-element data have been received for all the spruce bark samples (see Dunn, 1986).

2) **Landsat imagery:** Procurement of multi-data thematic mapper Landsat (earth satellite) data

[1]Resource Geophysics and Geochemistry Division, Geological Survey of Canada.

tapes for interpretation of individual images and comparison of images from different seasons. Ground resolution approximately 30 by 30 m (Investigator - J.R. Belanger).

Status: data tapes are on order.

3) MEIS (multi-detector electro-optical imaging scanner) flights: four aircraft flights over selected parts of the study area (Fig. 2). Digital data were obtained at 8 wavelengths scanned at spatial resolutions of 2 by 2 m (two flights) and 5 by 5 m (two flights). Data cover the 'red edge' of vegetation reflectance between 680 and 800 nm. In this portion of the spectrum, shifts in reflectance are related to stress such as that induced by enrichments (or depletions) of elements in the vegetations. Data analysis will investigate these shifts in reflectance and attempt to relate them to biogeochemical results.

Status: Flights were completed in August, 1986. Data are being compiled for evaluation. (Investigators - A. Rencz, G. Bonham-Carter).

Discussion

Clearly, the chances are infinitesimal that changes of a few parts per billion of gold in the vegetation will be detected from remote sensing studies. Furthermore, mineralization in the study area generally has few 'pathfinder' trace elements associated with the gold, so their effects on the vegetation are unlikely to be discernible by airborne sensors. However, alteration zones and any changes in major element chemistry of the rocks around gold mineralization may cause differential uptake of elements by the vegetation. Such changes can cause subtle shifts in spectral reflectance of the forest canopy, and may be identified from airborne and satellite sensors. With these principles in mind, the study has been launched to determine the

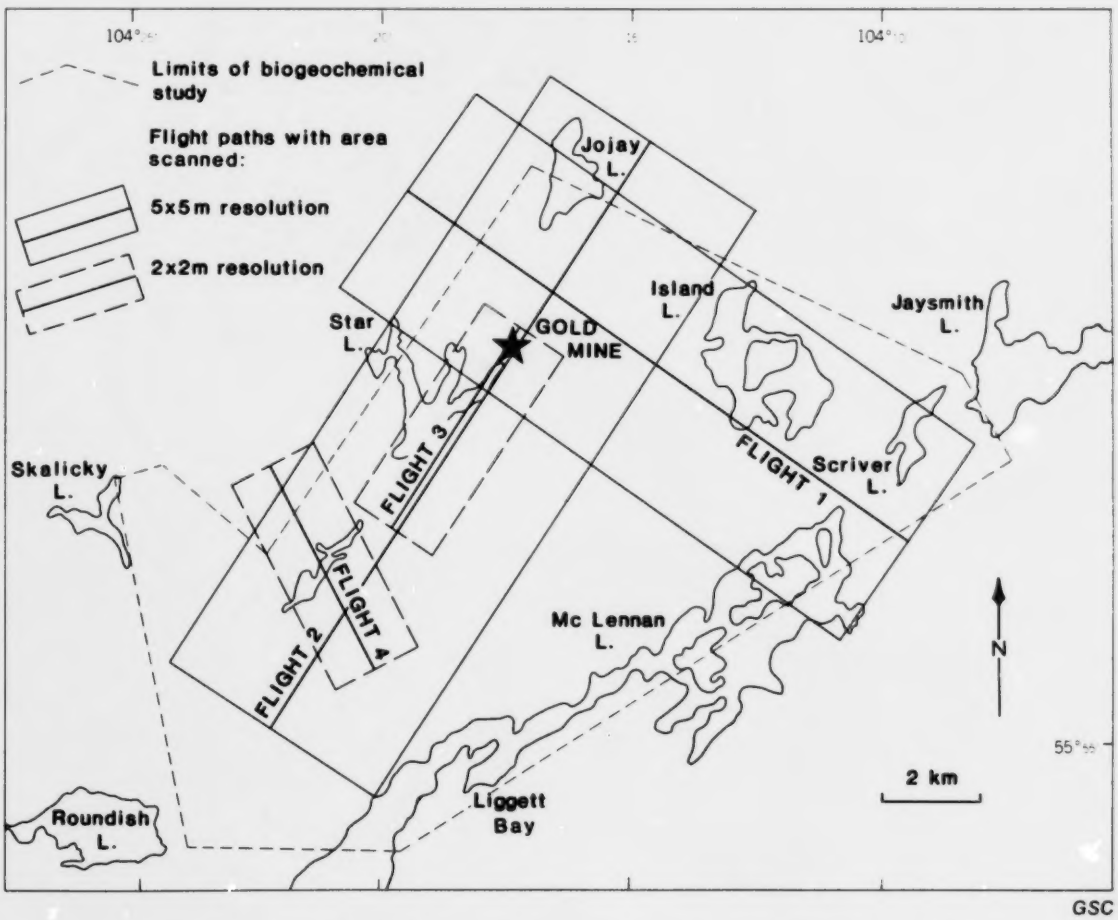


Figure 2 - Path of MEIS flights showing ground area scanned on each flight.

patterns of element concentrations in the vegetation, and attempt to relate these patterns to changes in spectral reflectance observed from remote sensing scans at different altitudes. If, for example, a certain reflectance is obtained over a zone of known gold mineralization, and biogeochemical data show an element pattern coincident with this zone, then the same combination of parameters can be sought elsewhere to assist in outlining hitherto undiscovered minerals.

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# Controls on Gold Mineralization in the Star Lake Pluton, La Ronge Domain

by K.H. Poulsen[1], D.E. Ames[1] and A.G. Galley[1]

Poulsen, K.H., Ames, D.E. and Galley, A.G. (1986): Controls on gold mineralization in the Star Lake Pluton, La Ronge Domain; in Summary of Investigations 1986, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 86-4.

During the 1986 field season, further mapping of the Star Lake Pluton and associated gold mineralization was carried out at 1:10,000 and 1:500 scale. Data were collected to test and extend concepts developed previously (Poulsen et al., 1985; Poulsen et al., 1986) to ascertain the fundamental controls on gold within this intrusion. This note describes the relationships between gold and the pluton itself, dykes which cut the pluton, mylonitic shear zones and products of hydrothermal alteration. Relevant illustrations can be found in the earlier publications cited above.

## The Pluton

The Star Lake Pluton is a late syntectonic intrusion, measuring 6 by 3 km and ranging from diorite to granite in composition. A smaller body, composed primarily of gabbro, lies to the north of the pluton and may be a satellite intrusion. The Star Lake Intrusion has been metamorphosed with common development of biotite and epidote at the expense of primary hornblende. The biotite defines a metamorphic foliation which parallels the margins of the pluton and is an indication that the body has undergone a weak to moderate penetrative strain. The marginal phases of the intrusion commonly contain agmatitic breccias with angular to subrounded metamorphosed xenoliths of volcanic and sedimentary country rocks. The patterns of internal zonation of compositional types have been established by further mapping. Internal contacts among the various plutonic phases are commonly gradational, but sharp intrusive contacts and intrusive breccias with cognate xenoliths have also been encountered. The distribution of gold within the pluton is independent of plutonic host rock type.

## Dykes

The Star Lake Pluton is cut by a swarm of dykes of composition varying from gabbro to aplite, but which are most typically quartz monzonitic; crosscutting relationships suggest that in general the most felsic dykes were the last to be emplaced. Of particular note are narrow tourmaline-bearing aplites in the vicinity of the Rod gold zone. The dykes in general strike N50°E and diamond-drill information and underground observations confirm their steep dip. The dykes range from a few centimetres to 10 metres in width and most commonly have sharp planar walls. In some places, amoeboid masses of dyke rock were noted to coalesce into a single dyke, suggesting that in some cases they were injected into unconsolidated plutonic host rocks. The dykes are widely distributed within the intrusion, and gold-bearing zones commonly contain some dyke material. There appears to be no direct genetic relationship between dykes and gold; the tourmaline-bearing dykes near the Rod zone may be an exception.

## Mylonitic Shear Zones

The geological features most directly related to the occurrence of gold-bearing quartz veins are ductile shear zones containing protomylonitic and mylonitic equivalents of the adjacent plutonic host rocks (Poulsen et al., 1986). Up to 30 m in width, the shear zones typically strike N60°E and dip steeply northwestward. They clearly postdate most dykes and the weaker metamorphic foliation in the pluton. Some shear zones are centred on dykes but in many cases shear zones independent of dykes, and dykes independent of shear zones have been encountered. The shear zones occur as an array of subparallel structures, typically spaced 400 to 500 m apart within the pluton. Our mapping indicates that at least seven of these, although they may commonly be composed of more than one branch, have significant strike length. From north to south they include:

1) the Decade shear which occupies the northwest margin of the pluton and hosts the Decade gold deposit, a past producer;

2) the Rod shear which has been traced for at least 1.4 km along strike and hosts several gold-bearing zones;

3) the Rush Lake shear which extends for at least 2 km and contains known gold mineralization;

4) the Blindman shear which has not yet been shown to yield significant gold concentrations;

5) the B shear, a N45°E-striking structure, which contains very little protomylonitic material but considerable quartz vein material without known gold;

[1]Mineral Resources Division, Geological Survey of Canada.
Project funded under the Canada component of the Canada-Saskatchewan Subsidiary Agreement on Mineral Development 1984-89.

6) the Star Lake shear which transects the entire pluton and has been mapped for 3.3 km; this shear hosts the 21 Zone deposit;

7) the Thin Lake shear which has been mapped over a length of 0.7 km at the eastern end of Thin Lake; position and orientation suggest that it is likely the extension of the zone hosting the Tamar occurrence to the southwest; this correlation plus other local observations give a possible strike extent of 3.7 km to this structure.

In addition, we have identified several shorter segments of shear zones, notably at the western end of Thin Lake, at the southwest end of Nameless Lake and along the northwest shore of Fork Lake. These may be more extensive but poor outcrop conditions preclude their complete definition along strike.

## Alteration

A notable feature of the Star Lake deposits, in contrast to similar deposits in Archean rocks (i.e., Bourlamaque Batholith, Quebec) is the rarity of chemical and mineralogical alteration adjacent to veins. Although visible bleaching of wall rocks has been noted in some occurrences (Poulsen et al., 1986), it is generally of such a local scale as to be of limited value as an exploration guideline. Late brittle fractures containing hematite and clay minerals are recognizable at the outcrop scale adjacent to gold mineralization at the Rod and 21 zone deposits. The iron sulphides at depth within these zones also are converted locally to hematite at mineral grain boundaries. Such oxidation could have also resulted in deposition of hematite in the fractures. The presence of clay minerals in the fractures indicates formation during late unroofing of the pluton. The presence of these fractures may be a useful exploration guideline in other parts of the intrusion because they may reflect the proximity of sulphides.

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# Gold-Tungsten-Copper-Molybdenum Mineralization in the Phantom Lake Area: Progress Report

by A.G. Galley[1] and J.M. Franklin[1]

Galley, A.G. and Franklin, J.M. (1986): Gold-tungsten-copper-molybdenum mineralization in the Phantom Lake area: progress report; in Summary of Investigations 1986, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 86-4.

A study of gold-tungsten-copper-molybdenum mineralization in the Phantom Lake region has been carried out over the past three years as part of a five-year program to study the gold metallogeny of the Flin Flon - Snow Lake Belt. During the first two field seasons of the study, it was observed that there is a gold-tungsten-copper-molybdenum association present in occurrences spatially associated with the Phantom Lake porphyritic quartz monzonite; that the mineralization is controlled by late faulting; and that there are several types of widespread alteration within the Phantom Lake and surrounding Boot Lake Intrusions. (Galley et al., 1984; Galley and Franklin, 1985; Pearson et al., 1986). The past field season was spent obtaining further structural data from the intrusions and surrounding volcanic rocks, examining the extent and type of alteration within the Phantom Lake and Boot Lake Intrusions, and the temporal relationship between the two intrusions.

## Geology

The Phantom Lake and Boot Lake Intrusions crosscut deformed Amisk Group metavolcanic rocks. A U-Pb zircon date of 1.82 Ga (R. McQuarrie, pers. comm.) on the Phantom Lake Intrusion makes it the youngest felsic intrusion in the belt to date. The Boot Lake Intrusion has not been successfully dated. Observation in 1986 suggests that both intrusions may have been emplaced during the last phase of deformation in the belt, which is marked by the extensive Cliff Lake Fault system immediately to the east. Neither of the intrusions has a penetrative foliation, except within discrete shear zones, but the surrounding rocks are strongly foliated. The southern and southwestern contacts between the Phantom Lake and Boot Lake Intrusions are gradational, suggesting a close time relationship. On Phantom Lake, an island is underlain by granodiorite intruding the hornblende porphyritic Boundary Intrusive, with both rock types crosscut by Phantom Lake dykes. As the Boundary and Phantom Lake Intrusions are thought to be syn- to post-third deformational phase in the area ($D_3$) and coeval (Syme and Forester, 1977), a similar age is indicated for the Boot Lake Granodiorite.

[1]Economic Geology and Mineralogy Division, Geological Survey of Canada. Project funded under the Canada component of the Canada-Saskatchewan Subsidiary Agreement on Mineral Development 1984-89.

## Mineralization and Alteration

In the absence of a penetrative foliation in the Phantom Lake and Boot Lake Intrusions, the dominant structural fabric consists of sets of west-northwest- to northwest-striking sinistral faults and north- to northeast-striking dextral faults. These are also the trends of dykes and gold-tungsten-copper-molybdenum mineralized zones, not only within the intrusions, but in the surrounding volcanic rocks. Many, but not all, of the mafic dykes in the Boot Lake Intrusion are strongly foliated by north- to northeast-trending shears. The principal gold deposits in the area, the Flin Flon Gold Mine and Henney-Maloney, are also located along north- to northeast-trending faults. An interplay of the sinistral and dextral fault systems may be responsible for the creation of dilatant zones into which metal-bearing fluids were localized.

Two types of widespread alteration are present in the area. One of these, starting 100 to 200 m inside the margin of the Phantom Lake Porphyry and continuing outward for at least 100 m into the Boot Lake Granodiorite is represented by a zone of intense fracturing, with deposition of hematite-epidote-quartz. This type of alteration is also observed in rocks adjacent to Phantom Lake Porphyry dykes intruding Boot Lake Granodiorite and Amisk volcanic rocks; there is no associated sulphide mineralization. The other type consists of quartz-carbonate-chlorite-pyrite veins in broad zones within the Boot Lake Intrusion. While the hematite alteration appears to be controlled by the Phantom Lake contact and the large northwest-trending Phantom Lake dykes, the chlorite-carbonate-pyrite veins are tensional north-northeast-trending gash veins related to north-trending dextral shear zones within the Boot Lake Intrusion. In relation to this, Pearson (1985) has suggested that 170° shears within the north-northeast-trending Rio Fault control high-grade gold pockets in the Flin Flon Gold Mine orebody.

## Summary

Investigations to date indicate that the Boot Lake and Phantom Lake Plutons are syntectonic with the third deformational phase ($D_3$) intrusions emplaced during the formation of the extensive Cliff Lake Fault zone along the Manitoba-Saskatchewan border. The relationship between fault sets, dykes

and mineralized zones within the intrusions and in the surrounding volcanic rocks would suggest a close temporal relationship between gold mineralization and the latest tectonic event in this portion of the Flin Flon - Snow Lake Belt.

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# An Investigation of Mafic and Ultramafic Intrusions in Northern Saskatchewan: Preliminary Findings

by Larry Hulbert[1]

Hulbert, L. (1986): An investigation of mafic and ultramafic intrusions in northern Saskatchewan: preliminary findings; in Summary of Investigations 1986, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 86-4.

The summer of 1986 marked the second field season of a four-year study aimed at obtaining a better understanding of the mafic-ultramafic intrusions in northern Saskatchewan. Field work in 1986 was carried out at the following localities: Dead Lake, Reef Lake, Gochager Lake, Bellows Lake, Bassett Lake, Neyrinck Lake, Fork Lake, Hetherington and Reindeer Lake, Gow Lake and Ant Lake.

## Dead Lake

Ni-Cu mineralization occurs in a pegmatitic gabbro at Dead Lake. Coarse sulphide blebs up to 1 cm in diameter, consisting of pyrrhotite, pentlandite, and chalcopyrite +/- galena are found in a pseudomagmatic textured rock. The grain size of the gabbroic rock increases in proximity to cross cutting granite veins. The precious metal contents of the mineralized samples are 15 to 21 ppb Pd, less than 15 ppb Pt and 158 to 265 ppb Au. The relatively high Au values, the galena association and the increase in grain size adjacent to the granitic veins suggests a hydrothermal rather than magmatic origin for this mineralization.

## Reef Lake

Disseminated sulphide mineralization in harzburgites was examined and analyzed for Pd, Pt and Au. The values ranged from 7 to 19 ppb Pd, less than 15 ppb Pt and 7 to 14 ppb Au.

## Gochager Lake

The Gochager Lake Intrusion was examined further during the 1986 field season. Fresh material discovered in core stored at Gochager Lake revealed that the pre-alteration host rocks to the mineralization were norites, websterites, feldspathic websterites and minor amounts of harzburgite. This intrusion is petrologically identical to the Logue Lake intrusion 34 km to the northeast. Additional analytical work confirms extreme depletion in precious metals. Mean values for the ultramafic-related mineralization in twelve samples are 26 ppb Pd, less than 15 ppb Pt and 4 ppb Au. Similar massive and disseminated sulphides related to the noritic host examined during 1985 have low mean values of 13, less than 15 and 7 ppb for Pd, Pt and Au respectively. The highest value recorded on the property is 144 ppb Pd.

The surrounding country rock sediments and volcanics are extremely rich in disseminated and massive concentrations of barren sulphides. It is felt that the bulk of the sulphur in the Ni-Cu sulphides has been derived from the country rock.

## Bellows Lake

Massive and disseminated Ni-Cu sulphides identical to those from Gochager Lake occur in a quartz diorite host at Bellows Lake. The mean Pd, Pt and Au values are 40, 15 and 46 ppb respectively.

The identical Ni/Cu ratios and grades of the sulphides, the occasional association of gabbroic fractions and the close proximity to the Gochager Lake Intrusion suggest that the magmatic-looking (non-shear or fracture- related) sulphides at Bellows Lake are magmatic and that some of the mafic bodies in the area are possibly coeval with granitic plutons of the Kruger Lake type.

## Bassett Lake

Sulphide-rich portions of the cumulus magnetite layers and associated gabbroic rocks were examined. All Pd, Pt and Au analyses revealed that the samples have values below the detection limits of 2, 15 and 1 ppb respectively. Similar low values were found in sulphide-rich magnetite layers within the Tow Lake Intrusion situated 30 km east of Lynn Lake, Manitoba. These findings, coupled with research on magnetite layers in the Bushveld Complex, suggest that Fe-Ti-V spinels are poor hosts for PGE mineralization relative to Cr-spinels.

## Fork Lake

Investigations on this body suggest that it is highly deformed and metamorphosed. However, relatively fresh peridotite was found in the central, less deformed portion of the intrusion and this material will be used for mineralogical, petrological and chemical investigations. Field examinations suggest that this body is poor in sulphide

[1]Economic Geology and Mineralogy Division, Geological Survey of Canada.
Project funded under the Canada Component of the Canada-Saskatchewan Subsidiary Agreement on Mineral Development 1984-89.

mineralization and is probably depleted in PGE, like most other intrusions in the La Ronge belt.

Hetherington and Reindeer Lake

Further investigations of the Helikian diabase (flood basalt association) intrusions in northern Saskatchewan were conducted during 1986. Excellent exposures of fresh quenched diabase and coarse-grained fractionation products were examined and sampled. Analytical work conducted on the samples taken during the 1985 field season in the Tremblay Lake and Howe Lake area disclosed anomalously high PGE contents for these sulphur-poor basaltic rocks. Values similar to those found in the chilled margins of the Bushveld Complex are not uncommon.

It is interesting to note that GSC Open File 1106, which surveyed 1,178 sample locations, recorded its highest lake sediment Cu value of 100 ppm from a lake underlain by one of these diabase bodies. The lake in question is 6.4 km southeast of Howe Lake and occurs at UTM co-ordinates 507811mE, 6289591mN. Fortuitously, the author investigated the diabases at this locality in 1985 and subsequent analyses disclosed mean Pd, Pt and Au values of 24, 16 and 4 ppb respectively based on 34 samples in these apparently sulphur poor rocks (250 ppm). The potential for these bodies to give rise to PGE-enriched sulphides should not be underestimated.

Neyrinck Lake

The Cu-sulphide mineralization in the Neyrinck Lake gabbro-diorite intrusion was investigated to establish the precious metal content and the petrological character of this body.

The petrological nature of this intrusion is unlike any other examined in the La Ronge belt, and the only other intrusion of similar character was found at Carr Lake in the Lynn Lake area of Manitoba. The bulk of the intrusion consists of a coarse-grained anorthositic gabbro or diorite (anorthite content yet to be established). The predominant mafic phase is hornblende after pyroxene. However, numerous samples containing fresh primary Fe-rich looking olivines and pyroxenes were found. The discovery of these fresh magmatic minerals will be of tremendous aid in getting a better understanding of this rather unusual looking intrusion.

The mean Pd, Pt and Au values, based on thirty-four samples, are 72, 56 and 111 ppb respectively. The maximum values obtained were 166, 117 and 443 ppb respectively. Relative to other magmatic Cu-Ni mineralization in the La Ronge belt, these sulphides are very enriched in Au. The high values may be suggesting a genetic link between this calc-alkaline body and that of the Star Lake Intrusion a few kilometres to the north.

Gow Lake

Samples from the east side of Gow Lake reported to contain 0.20 oz./ton Pd were investigated. Subsequent sampling and assays disclosed that Pd, Pt and Au do not exist at levels in excess of 8, 15 and 12 ppb respectively at the reported locality. One can only conclude that the high Pd values documented at this meteorite impact feature are erroneous.

Sedimentary Environments

To date, synsedimentary sulphides from Alligator Lake, George Lake, Borys Lake, Forbes Lake, Kruger Lake, Gochager Lake, Gow Lake, Nemeiben Lake and Campbell River have been investigated for their PGE content. The highest Pd and Pt values recorded are 22 and 8 ppb respectively.

Summary

Field investigations followed up by PGE assays suggest that the intrusions investigated in 1986 in the La Ronge greenstone belt are poor hosts for platinum and palladium.

Numerous samples containing pristine magmatic silicates and oxides have been encountered during this summer's investigations. These, in conjunction with similar material collected last year, are presently being subjected to Nd-Sm and Rb-Sr isotopic investigations at the University of Saskatchewan. It is anticipated that a better understanding of the age, intensive parameters and metallogenesis of the magmas will be gained from the radiogenic and mineralogical studies on such material. Also, the presence of fresh magmatic minerals is permitting correlation of the various intrusions in the LaRonge - Reindeer Lake - Lynn Lake greenstone belt.

From the limited amount of data gathered on synsedimentary sulphides in the various study areas, it would appear that this environment is poorly endowed in Pt and Pd.

# The Kisseynew Gneisses of Saskatchewan: Update

by K.E. Ashton, K.J. Wheatley, D. Moser, D. Paul and K.H. Wilcox[1]

Ashton, K.E., Wheatley, K.J., Moser, D., Paul, D. and Wilcox, K.H. (1986): The Kisseynew Gneisses of Saskatchewan: Update; in Summary of Investigations 1986, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 86-4.

Regional 1:50,000 scale mapping of the southern flank of the Kisseynew Gneiss Belt was extended this summer to include the area bounded by the Manitoba border and Phelan, Wildnest and Annabel Lakes.

The stratigraphy consists of a volcanic-sedimentary suite and an unconformably overlying sequence of arenites. This contact is marked by a basal polymictic conglomerate in the south but appears to be transitional further north.

The earliest structures consist of tight to isoclinal, near-recumbent folds and possible low-angle faults. Superimposed upon these structures are at least two nearly orthogonal phases of megascopic folding which have produced a complicated interference pattern.

The metamorphic grade ranges from lower amphibolite facies at Annabel Lake to middle-upper amphibolite facies to the north and west. Additional occurrences of relict kyanite were discovered, suggesting depths of burial equivalent to in excess of 4.8 kb.

The "stratigraphic" subdivision of the Kisseynew Gneisses into the Nokomis and Sherridon Groups is poorly constrained, and recent work elsewhere casts some doubt as to the origin and age of the type Sherridon Group gneisses. The results of this study suggest that the volcanic-sedimentary suite of the Kisseynew Gneisses likely represent the high-grade equivalents of the Amisk Group and that the unconformably overlying arenaceous sequence correlates with the Missi Group. The use of the terms "Nokomis Group" and "Sherridon Group" has, therefore, been abandoned.

## General Geology

This report updates a four-year project initiated in 1985 to provide a better understanding of the geology, and particularly the stratigraphy, of the Kisseynew Gneisses. Early findings have been outlined previously (Ashton and Wheatley, 1985, 1986) and a more detailed report and map based on the 1986 field work will be presented in Current Research, Part B, Geological Survey of Canada, Paper 87-1B. In 1986, the second year of fieldwork, mapping was carried out by a five-person crew over an area bounded by the Manitoba border and Phelan, Wildnest and Annabel Lakes. Some additional work was also carried out along the Hanson Lake Road between Hamell Lake and the Sturgeon-Weir River.

The oldest rocks in the area are part of a metamorphosed, volanic-sedimentary suite consisting of intermediate to mafic and minor felsic flows, and mixed volcaniclastic rocks in the southern and western parts of the area which grade into mainly epiclastic wackes to the northeast. Most of the metavolcanic rocks consist of hornblende±garnet±biotite±clinopyroxene gneisses, but felsic to mafic calc-silicate rocks and siliceous quartzofeldspathic gneisses from the Wildnest Lake area have also been included as altered equivalents. The associated epiclastic rocks include extensive, originally poorly layered wackes and minor turbidites. Most are garnet-biotite± sillimanite gneisses, but hornblende-bearing varieties are common, particularly adjacent to rocks of the volcanic suite. A more micaceous sequence of biotite-white mica±sillimanite schists and wackes extending eastward from northern Mari Lake (Macdonald, 1975) is also grouped with the epiclastic sequence and is thought to be correlative with schists mapped further east in Manitoba (Pollock, 1964).

The volcanic-sedimentary suite is unconformably overlain by a sequence of clastic arenaceous paragneisses. In the south, the contact is marked by a basal polymictic conglomerate, the composition of which is locally quite variable. Recognizable clasts, however, are predominantly made up of rocks from the volcanic-sedimentary suite with a lesser component derived from granitoid and quartz vein material. The conglomerate is locally interlayered with, and gradational upward into biotite±magnetite± garnet±sillimanite±white mica arenites and minor hornblende-bearing calc-arenites and wackes. The basal conglomerate was not recognized in the north, possibly due to intense deformation or the absence of the unit due to nondeposition, suggesting that the unconformable relationship may be restricted to areas near the volcanic centres and that more distally the arenites may lie directly upon the volcanic-sedimentary suite or be separated from it by a thin sequence of feldspathic quartzites, mica schists and wackes. This quartzite-schist-wacke sequence also occurs in a belt extending through Tyrrell and Wildnest Lakes; if the sequence is a distal facies equivalent of the basal conglomerate,

[1]Contracted project by Geological Survey of Canada with funds provided under the Canada component of the Canada-Saskatchewan Subsidiary Agreement on Mineral Development 1984-89.

there may be a major structural discontinuity in that area.

Dioritic to gabbroic dykes intrude both the volcanic-sedimentary suite and the arenaceous sequence, and are particularly common at northern contacts between the two.

The entire area has been intruded by extensive, pre- to syntectonic granodiorite. Hornblende-bearing granodiorite makes up the majority of plutons, but a biotite leucogranodiorite exhibiting nebulitic layering occurs in the southern Mari Lake area. Both varieties of granodiorite are thought to postdate the supracrustal rocks, although contact relationships with the arenaceous sequence could not be determined for all plutons.

Pink and white varieties of syn- to posttectonic pegmatite dykes represent the last magmatic activity in the area.

## Structure

The regional structure has been outlined previously (Ashton and Wheatley, 1986). The following is a brief summary with new observations based on 1986 mapping. The earliest deformation is considered to have produced the regional gneissosity and was probably accompanied by tight to isoclinal folding. This was followed, perhaps as part of the same deformational event, by the extensive development of tight to isoclinal, gently inclined, gently plunging folds which locally exhibit shearing along the axial planes. The majority of minor folds and a strong coaxial regional stretching lineation were also developed at this time. Zones of altered schistose rocks, which were most commonly observed at contacts between the volcanic-sedimentary suite and the arenaceous sequence, may be zones of major layer-parallel shearing related to this early phase of deformation.

At least two phases of late folding have produced extensive fold interference at map scale. The earlier of the two phases is represented by a number of megascopic, open to near isoclinal, gently north-trending and north-plunging folds which extend from approximately Tyrrell Lake to the northern boundary of the map area. These are refolded by a set of broad, open, upright, east-trending flexures, producing an interference pattern which is transitional between types 1 and 2 of Ramsay (1967).

A set of east to southeast-trending, northeast-plunging folds east of southern Mari Lake marks the edge of a structural domain dominated by east-west structural fabrics in Manitoba. The relationship beween this phase and the deformation described has not yet been determined.

Late brittle faulting is marked by minor brecciation and by fractures filled with chlorite and epidote. Examples include a north-striking and apparent left-lateral fault set extending from Flin Flon to Mari Lake, and a possibly conjugate set of northeast and northwest-striking faults in the Wildnest Lake area.

## Metamorphism

The metamorphic grade increases from lower amphibolite facies in the Annabel Lake area to middle-upper amphibolite facies immediately to the north and west. A gradational increase in grain size in those directions indicates that the metamorphic gradient extends to the boundaries of the area mapped, although it appears to be steepest at the boundary between the volcanic belt and Kisseynew Gneisses.

Two new occurrences of kyanite were found on southern Mari Lake and southern Wildnest Lake, near previously described occurrences (Ashton and Wheatley, 1986). As at the other localities, the kyanite appears to be a relict phase occurring in rocks characterized by the assemblage sillimanite-garnet-biotite-quartz-feldspar. It is noteworthy that these occurrences are generally either at or near the strongly deformed contacts between the volcanic-sedimentary suite and the arenaceous sequence. Despite its relict nature, the composition and texture of the kyanite-bearing rocks indicate that the assemblage kyanite-garnet-biotite was stable during prograde metamorphism. As metamorphic pressures in excess of 4.8 kb are required to stabilize such an assemblage (Carmichael, 1978), it is suggested that tectonic thickening was likely involved in the development of the Kisseynew Gneiss Belt.

Relict staurolite was identified in the Mansask Lake area, where it had been previously reported by Macdonald (1975), and at the new kyanite occurrence at the south end of Wildnest Lake.

## Stratigraphic Interpretation

The high-grade rocks in the Kisseynew Lake - Mari Lake area were originally called the Kisseynew Gneisses by Bruce (1918), to demonstrate their uncertain relationship to the supracrustal rocks of the Flin Flon Volcanic Belt. While extending the regional mapping to the west, Wright and Stockwell (1934) assigned similar high-grade gneisses to the Amisk and Missi Groups of the Flin Flon area rather than using the term "Kisseynew". Byers and Dahlstrom (1954) did not attempt a stratigraphic subdivision of the high-grade rocks, but assigned them to the Kisseynew Group and agreed that they were likely the metamorphosed equivalents of the Amisk and Missi Groups.

In Manitoba, the Kisseynew gneisses were divided into the Sherridon Group, comprising interlayered quartzofeldspathic paragneisses and

ortho-amphibolites hosting the Cu-Zn mineralization at Sherridon (Bateman and Harrison, 1946), and the Nokomis Group, comprising micaceous gneisses and para-amphibolites in the Batty Lake area (Robertson, 1953). This terminology has since been extended to other areas (Robertson, 1953; Bailes, 1971; Zwanzig, 1983, 1984; Ashton and Wheatley, 1985, 1986; McRitchie, 1985; Schledewitz, 1985), but in the process has undergone significant modification. Bailes (1971) suggested that the Nokomis metasedimentary gneisses correlate with Amisk Group epiclastic rocks, but was uncertain about the "Nokomis" hornblende gneisses, which were recognized as a lithological rather than a stratigraphic unit.

The preliminary findings of this study are consistent with that correlation, although it is further suggested that the entire Kisseynew volcanic-sedimentary suite may be correlative with the Amisk Group. Amisk volcanic and volcaniclastic strata swing from an east-west strike in the Tyrrell-Annabel Lakes area to a northerly trend in the vicinity of Wildnest Lake. The Kisseynew metamorphic front maintains an approximately east-west orientation in that area and overprints the Amisk stratigraphy. It appears, therefore that the Kisseynew "front" marks a change in metamorphic grade and structural style rather than a stratigraphic contact.

The age and origin of the more quartzofeldspathic Kisseynew gneisses are more problematic. Following an earlier suggestion by Bateman and Harrison (1946), Bailes (1971) correlated the Sherridon Group with the Missi Group. A re-examination of the Sherridon Group at Sherridon by Froese and Goetz (1981), however, led to the expansion of Sherridon Group stratigraphy to include garnet-biotite gneisses, calc-silicate rocks and marbles, most of which have no low-grade equivalents in the Missi Group. Froese and Goetz (1981) drew attention to this lithological problem and other marked differences between the two groups, but the assignment of a wide variety of assorted Kisseynew rocks to the Sherridon Group, and their subsequent correlation with the Missi Group, has continued (Zwanzig, 1983, 1984; Ashton and Wheatley, 1985, 1986; McRitchie, 1985).

Further doubt on the validity of the correlation between the Sherridon Group at Sherridon and the Missi Group has been cast during the course of this study, as a suite of quartz-rich, quartzofeldspathic gneisses and calc-silicate rocks, strikingly similar to the Sherridon succession described by Froese and Goetz (1981), was recognized in the Wildnest Lake area. Composition, structural relationships and lithological associations all indicate that these rocks are part of the volcanic-sedimentary suite, and are likely high-grade, altered rocks of the Amisk Group. It is therefore suggested that the origin and age of the Sherridon Group at Sherridon deserve further study.

In view of these difficulties, use of the terms "Nokomis Group" and "Sherridon Group" is being discontinued. The sequence of polymictic conglomerates and arenites previously assigned to the Sherridon Group (Ashton and Wheatley, 1985, 1986) are tentatively correlated with the Missi Group.

## Acknowledgements

We are grateful to several geologists for sharing their knowledge of the regional geology. J.G. Pearson, Creighton Resident Geologist, Saskatchewan Energy and Mines Geological Survey, and E.C. Syme, Manitoba Mineral Resources Division, showed us various localities within the Flin Flon volcanic belt. E. Froese, Geological Survey of Canada, led a field trip to the Kisseynew Lake, Duval Lake and Sherridon areas, which promoted useful discussions with D.C.P. Schledewitz, Manitoba Mineral Reources Division, T.M. Gordon, Geological Survey of Canada and S.L. Jackson, Queen's University. One of us (K.E.A.) also had the benefit of a guided tour of the Snow Lake area, courtesy of E. Zaleski, University of Manitoba.

We are grateful for having the opportunity of discussing the regional geology with R. Macdonald, Assistant Director, Saskatchewan Geological Survey, J.F. Lewry, University of Regina, and M.E. Bickford, University of Kansas, during a one-day geochronology sampling tour. Discussions with R.R. MacQuarrie, Hudson Bay Exploration and Development Company Ltd., G.R. Parslow, University of Regina, and B. Davis, Greenstone Resources Ltd., were also very instructive.

The logistical assistance provided by A.T. Baumgartner, Hudson Bay Exploration Company and Development Ltd., R. Ferguson, Parsons Airways Northern Limited, J.G. Pearson and G.R. Parslow was greatly appreciated.

We are especially indebted to E. Froese for continued encouragement and for offering several helpful suggestions while critically reviewing an early draft of this report.

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OTHER NORTHERN STUDIES

# The Bassett Lake Mafic Intrusion: Preliminary Report

by I. Graham[1], B.R. Watters[1] and L. Hulbert[2]

Graham, I., Watters, B. R., and Hulbert L. (1986): The Bassett Lake mafic intrusion: preliminary report; in Summary of Investigations 1986, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 86-4.

The Bassett Lake mafic intrusion is situated on and immediately south of Bassett Lake in the southernmost part of the Central Metavolcanic Belt of the La Ronge Domain. The Bassett Lake area mainly comprises a suite of plutonic mafic-ultramafic rocks bounded by a predominately intermediate to mafic volcanic country rock assemblage to the south, a compositionally variable granodioritic body to the northwest and a diorite intrusion to the east.

## Present Project

Detailed mapping and sampling of the mafic intrusion has been carried out and will form the basis for mineralogical and geochemical studies. Samples of drill core from the Triangle Lake area in the central part of the body will constitute an important component of these studies.

Major aims of the study will be to determine the nature of the intrusion, its origin and relationships to other rock units in the La Ronge Domain, and the potential for mineralization involving elements of the platinum group, vanadium, titanium and chromium. A variety of analytical techniques, including electron probe microanalysis, will be employed to investigate the mineralogy, mineral zoning, chemical characteristics and phase relations of oxide and sulphide minerals.

## Previous Work

The earliest reference to work done in the area is that of McLarty (1936) who mapped the area as part of a regional project. An airborne magnetic survey over the "basic and ultrabasic" rocks in the area for the Saskatchewan Department of Mineral Resources in 1953 indicated magnetic highs in the Triangle Lake area (Fig. 1).

Trenching of the sulphide showings in 1957 and 1961 covered the claim area held by A. Studer. Beck (1959) reported pyrite, pyrrhotite and chalcopyrite from a pit blasted at the main showing. In 1965, further airborne electromagnetic and magnetic surveys were flown by the Great Plains Development Co. of Canada Ltd., and the Don Fisher Syndicate undertook a ground electromagnetic survey. Regional mapping by Padgham (1960) included a report on the "Bassett Lake Gabbro", in which he referred to chloritized and epidotized hornblende gabbro and the development of some anorthosite. He also noted chalcopyrite, pentlandite, pyrrhotite and pyrite mineralization.

Richards (1964) described pyrrhotite and pyrite mineralization in a variety of gabbroic rocks from five diamond-drill hole cores from the Bassett Lake body. Reynolds (1967) subsequently mapped the area and reported a significant development of pyroxenites in a predominantly dioritic body, the surrounding rocks including granulites, granitic gneisses and volcanics.

Recent work by Harper (1982) included an investigation of both drill core and surface geology in the Triangle Lake area. The study was primarily an economic evaluation, and particular attention was given to the magnetite-rich rocks and their potential as an iron ore. Layered gabbro, olivine gabbro, minor peridotite and anorthosite are described by Harper (1982).

## Intrusive Mafic Rocks

The most common rock types in the Bassett Lake Intrusion are variably uralitized and hornblendic medium-grained to very coarse-grained gabbros. These are commonly foliated though locally massive or display only a weak fabric.

On weathered surface the rock appears very dark, except where 'leucogabbro' is developed. The leucogabbro has well-developed plagioclase laths typically altered to aggregates of 'saussurite' as a result of deuteric processes and/or incipient metamorphism. Alteration of the plagioclase also occurs in the more mafic gabbros, although these rocks commonly display clearer and in places visibly zoned plagioclase crystals. Such zoning is due to inclusions of pyroxene, spinel and iron oxide.

The coarse-grained gabbroic rocks contain hornblende, occurring as large poikilitic plates. Secondary amphibole ("uralite") observed in some thin sections is predominately actinolite, with very minor nonpleochroic tremolite. Carlsbad twinning of the plagioclase is recognized in some hand specimens. A thin section from a core sample of gabbro from the Triangle Lake area shows

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Project funded under the Canada component of the Canada-Saskatchewan Subsidiary Agreement on Mineral Development 1984-89, with some logistic support from the Saskatchewan Geological Survey.

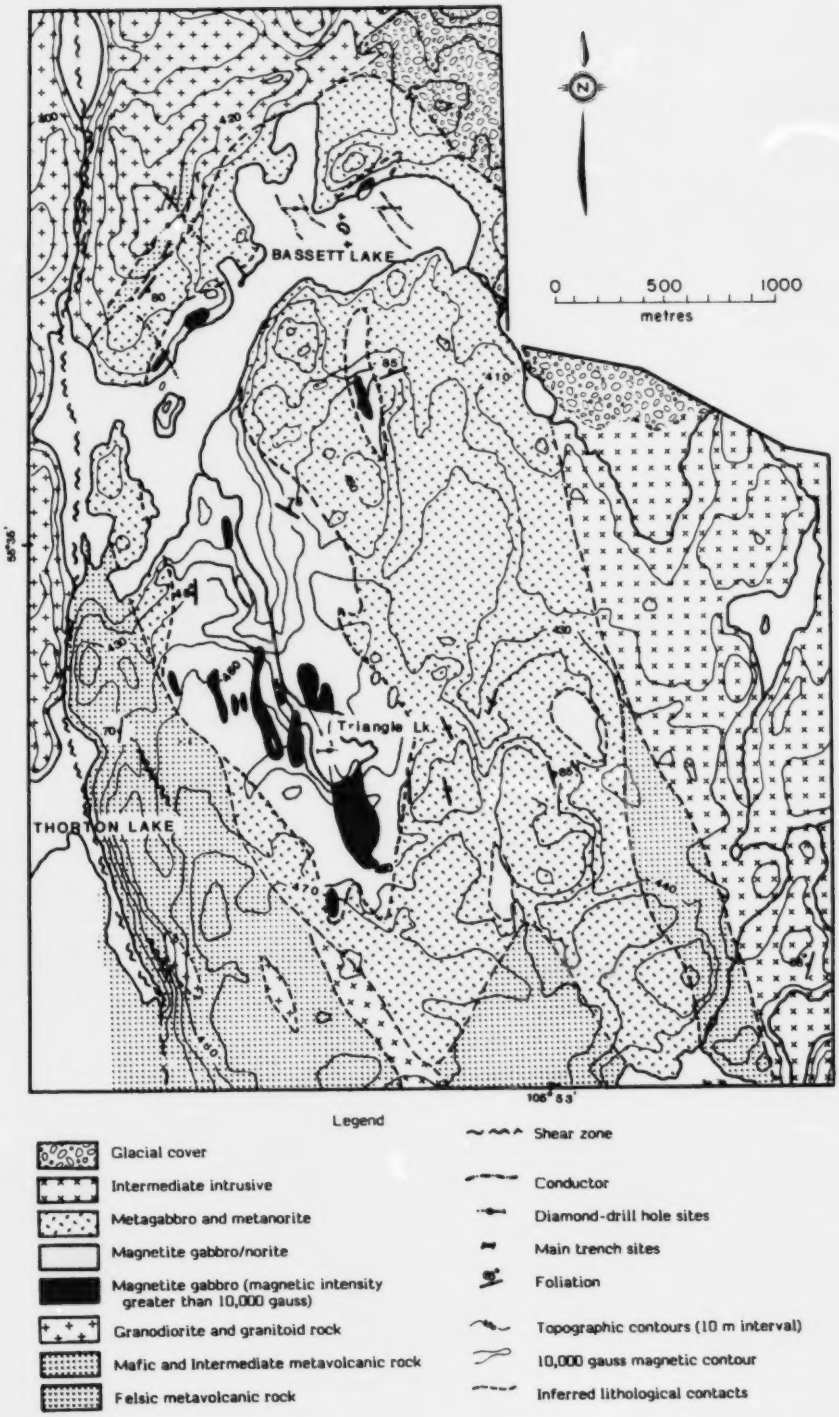


**Figure 1 - Preliminary geological map of the Bassett Lake mafic intrusion.**

development of augite (with possible pigeonite exsolution lamellae), zoned calcic labradorite and possibly late-magmatic hornblende.

Norite has been identified in the field and in thin section from the Triangle Lake area and may represent the "mottled type metagabbros" referred to by Harper (1982). These rocks are commonly weakly and more rarely strongly magnetic. In hand specimen they show oikocrystic development of hypersthene. The orthopyroxene crystals are medium grained, idiomorphic and bronze toned, and are responsible for the highly reflective, mottled outcrop surfaces common in the Triangle Lake area. Orthopyroxene observed in noritic horizons along the north shores of Bassett Lake is somewhat finer grained and 'sugary' textured with poorly formed crystals. Both ortho- and clinopyroxenes show evidence of high temperature alteration by hydration to amphibole. These rocks also contain plagioclase, commonly zoned and in the range calcic andesine to sodic bytownite, small flakes of hematized dark brown biotite, various amounts of opaque minerals and accessory apatite. Opaque minerals have not yet been fully identified but include magnetite, ilmenite, possibly chromite and trace sulphides such as pyrrhotite, pyrite and chalcopyrite.

Areas underlain by norite and gabbro commonly have smooth, rolling and densely wooded hills. Outcrop is not abundant except along the shores of Bassett Lake and on steep hillsides.

Magnetite-rich gabbro and norite are concentrated in the Triangle Lake area and along the western flank of the body. These melanocratic rocks contain up to 30 percent opaque minerals, the major component of which is probably magnetite. Although most of the noritic rocks contain opaque minerals, 'normal' norite is regarded here as that containing less than about 15 percent opaques in the mode. The textures are granular and somewhat anhedral, except where individual crystals are enclosed by magnetite and where subhedral crystal development occurs.

Very highly magnetic ultramafic rocks (Fig. 1), typically exhibit a surface magnetic intensity in excess of 10,000 gauss (Great Plains Development Co. of Canada Ltd., surface EM survey). One thin section of such an ultramafic rock (from diamond-drill core in the Triangle Lake area) contains approximately 60 percent opaque minerals, 20 percent olivine (including alteration products such as iddingsite and minor antigorite), augite and minor oligoclase or andesine. Reynolds (1967) mapped 'pyroxenites' in the Bassett Lake intrusion, but no rocks of this type were identified during the recent field study.

Anorthosite occurs in most parts of the Bassett Lake body where layering is well developed. This rock type has a well-developed granular cumulate texture and is more leucrocratic than the more common leuco- or anorthositic gabbro. It contains as little as 5 percent mafic minerals (usually hornblende), as well as saussuritized plagioclase feldspar. The anorthite content of the feldspars cannot be determined because of the alteration.

"Magnetite anorthosite" containing approximately 10 to 15 percent magnetite, occurs at a locality near Triangle Lake Creek.

Well-developed layering is present mainly in the northern and western parts of the body, and occurs on a scale varying from 1 and 2 cm to over 2 m. The layering is commonly compositional, but textural layering is also developed. To the west of Bassett Lake, in the area of very high magnetic intensities (Fig. 1), rhythmic layering on a scale of several centimetres is very well developed. The layers alternate in composition between an intensely magnetic "magnetite gabbro" and completely nonmagnetic leucogabbro.

A series of large-scale blocky "breccias" occur along the eastern contact zone of intrusion; angular blocks composed of fine- to medium-grained gabbro are set in a matrix of quartz dioritic to "leucogabbroic" material. The angular gabbroic blocks may be the result of disruption of the wall rocks of the Bassett Lake body during intrusion of the dioritic magma.

Veins of graphic-textured leucocratic granodiorite intrude the Bassett Lake body mainly in the north and west, but also in the northern-central parts of the intrusion. Variably developed in these regions, the vein margins range from sharp to diffuse. Quartz is concentrated towards the centres of the veins, whilst large hornblende crystals up to 7 cm in length are developed adjacent to the contacts. Pockets of predominantly uralitized mafic minerals occur in gabbroic host rocks adjacent to the veining, suggesting a genetic relation with the veins.

## Geology of the Country Rocks

The intermediate and mafic metavolcanics to the southwest of the Bassett Lake Intrusion are composed predominantly of crystal tuffs with lesser mafic flows and minor volcanogenic sedimentary units. Rocks along the shores of Thorton Lake have been intensely sheared, and minor shearing occurs elsewhere in the volcanics, en echelon to the main shear zone. Contact relationships between the volcanic rocks and the gabbroic rocks of the Bassett Lake body could not be established due to the absence of suitable outcrops.

Diorite and quartz diorite observed to the east of the mafic intrusion are medium to coarse grained, generally hornblendic and foliated. The predominant diorite contains more hornblende than the quartz diorite which in places is extremely leucocratic. Quartz diorite also occurs in

association with the breccias at the contact zone between the Bassett Lake gabbro and the diorite.

Granodioritic rocks outcropping to the east of Bassett Lake are compositionally variable, in places appearing granitic. A number of rafted "blocks" are present in the granodiorite, the largest xenolith recognized being a rhyolitic metavolcanic (indicated as "acid volcanics" in Fig. 1). The north-trending shear zone in the west, well developed in the granodiorite, is a major zone of mylonitization over 50 m wide in places. This shear zone extends northwards through Beaudry and Fault Line Lakes (Thomas, pers. comm.) and southward through Thorton Lake (Padgham, 1960).

## Summary

The Bassett Lake body is intrusive into predominantly metavolcanic rocks and is bounded to the east and northwest by later diorite and granodiorite respectively. The intrusion mainly comprises gabbro, norite and minor anorthosite. Magmatic magnetite is variously developed, resulting in a region of anomalous positive magnetic intensity. Much of the intrusion has been deuterically altered and a graphic granodioritic veining is commonly developed. The central parts of the body characteristically show primary magmatic layering.

## Acknowledgements

The project is supported by a research contract with the Geological Survey of Canada. Logistic support from the Saskatchewan Geological Survey for some aspects of the field work is gratefully acknowledged. K. Haynes, D. Thomas and C. Harper are thanked for their assistance during the field season.

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# Quaternary Geology of the Sulphide - Hebden Lakes Area Applied to Prospecting for Gold

by Janet E. Campbell[1]

Campbell, J. E. (1986): Quaternary geology of the Sulphide - Hebden Lakes area applied to prospecting for gold; in Summary of Investigations 1986, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 86-4.

The Saskatchewan Research Council has initiated a project in the Sulphide - Hebden Lakes area (Fig. 1) to document such Quaternary geology conditions as the type, distribution and stratigraphy of deposits; the source of materials; and the direction and distance of transport. This information will be used to determine the most useful sampling media and the most effective techniques for drift prospecting.

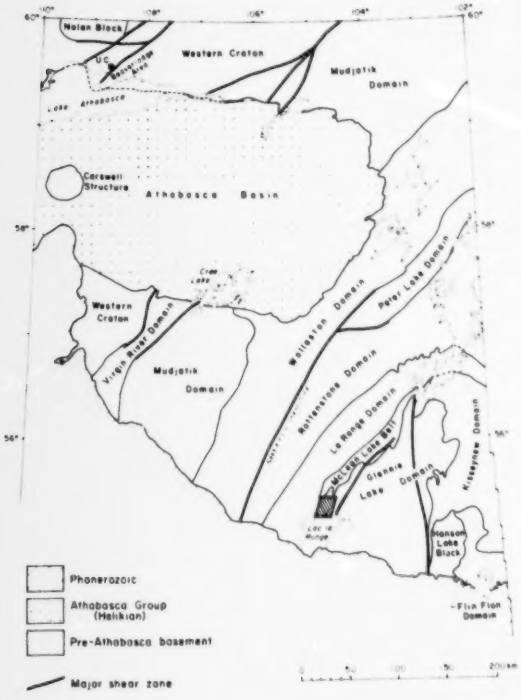


Fig. 1 - Location of the study area.

The study area of 240 km$^2$ coincides in part with the area of bedrock mapping being carried out this year by the Saskatchewan Geological Survey. This region of the La Ronge Belt was chosen because of the presence of known gold deposits and showings, and its complex Quaternary geology, which includes the influence of Lake Agassiz.

[1]Resources Sector, Saskatchewan Research Council, Saskatoon.

A summary of this summer's field investigations and some preliminary observations are included in this report, together with a preliminary mapshowing the distribution of surficial deposits (sheets 1 and 2, map pocket). The final SRC report to be published at a later date will include the results and interpretation of all work and analyses, and will be similar in scope to the report on the Waddy Lake area (Campbell, 1986).

## Procedure

After airphoto interpretation the surficial geology was mapped at 1:20,000 scale. Ground-checking was carried out at 235 sites, mostly by hand-augered holes or small pits dug to an average depth of 0.8 m.

Subsurface stratigraphic information was obtained by drilling 19 power-augerholes along Highway 102 and the Stanley Mission Road at depths ranging from 1.5 to 12.5 m and averaging 4.9 m. It is assumed that most holes reached bedrock although this is not certain because the auger drill cannot discriminate bedrock from very large boulders. Basal till was encountered in all but three holes.

Surface samples representative of the various deposits were collected, from the C-horizon where possible, with an emphasis on till.

Eighty-four bulk till samples, including 12 from augerholes, weighing 5 to 8 kg were collected in all. Where possible, the samples were taken from the up-ice side of highlands, ridges and outcrops.

## General Geology

Drift cover in the Sulphide - Hebden Lakes area is thin in comparison to the Waddy Lake area (Campbell, 1986). The surficial geology map (sheets 1 and 2, map pocket) shows the following percentage distribution of materials: bedrock (30), glacial till (35 to 40), glaciolacustrine (10 to 15), organic (10), and glaciofluvial (less than 10).

Based on information obtained from the augerholes and exposures examined, the complete stratigraphic succession is:

6) Organic material
5) Brown silty-sand till
4) Lacustrine sediments (sand, silts, clays)

3) Fluvial sediments (gravels, sands)
2) Grey/brown sandy till
1) Bedrock

Some or all of these units above bedrock are locally absent.

Bedrock

Outcrop is relatively abundant but is commonly masked by moss and lichen. The predominant rock types are metavolcanics, metasediments and felsic to mafic intrusives (Forsyth, 1968). The high relief of the exposed bedrock and the limited overburden drilling in the Sulphide - Hebden Lakes area suggest a highly variable bedrock topography.

Glacial Till

Two tills previously detected in exposures and augerholes in the region (Schreiner, 1984) were confirmed during the present investigation. These tills vary considerably in texture, composition, colour and appearance throughout the study area. This reflects the source material, mode of deposition and the effects of postdepositional processes. The surface till is generally weathered and/or reworked making identification difficult.

The lower till is commonly grey to brownish-grey in colour, and dense with a silty-sand matrix containing abundant granules. Subangular to angular clasts comprise 40 to 60 percent of the deposit. This till reflects the local bedrock lithology. The grey till is mainly derived from mafic intrusives, metasediments and/or mafic to intermediate volcanics whereas the till originating from felsic to intermediate intrusives tends to be brownish and more sandy.

Although the upper till is thin and discontinuous, it is more prevalent than in the Waddy Lake area (Campbell, 1986). At all 20 sites recorded, the till is less than 100 cm thick. The upper till is most commonly brown, often due to oxidation, with a silty-sand matrix containing a lower percentage than the lower till of smaller and more rounded clasts. The composition of this till reflects the incorporation of overridden stratified sediments, during a process thought to be related to a minor readvance of ice into the Lake Agassiz basin (Schreiner, 1984).

Glaciofluvial Deposits

Less than 10 percent of the study area is covered by glaciofluvial sand and gravel, occurring mainly in small channel-like depressions, as in the northeast. A broad belt of interlobate ice-contact deposits extends along the western edge of the area (Schreiner, 1984).

The portion within the study area varies considerably in width but is generally very narrow. The widest section is around Naniskak and Teneycke Lakes. A large outwash sand plain extends southwest from Lovell Bay (Hebden Lake) to Pechey Lake. Several sandy areas appear to be transitional between fluvial and lacustrine environments, as for example, the region surrounding Stewart Young Bay on Sulphide Lake.

Glaciolacustrine Deposits

Sandy silt is the predominant glaciolacustrine material, although fine sand and clayey silt are also found. These sediments are commonly massive. Although glacial Lake Agassiz covered much of the study area, their distribution and thickness is very discontinuous and variable, largely due to the rugged topography.

Glaciolacustrine sediments were found at a maximum elevation of 419 m in four locations. Wave-cut terraces and raised beaches at approximately 427 m are the highest evidence of lake level yet found in the study area. Wave-cut terraces are numerous, commonly ringing highlands and occurring in steplike series. Washed till and boulder lags also provide some indication of the extent of the glacial lake.

Organic Deposits

Most of the small lakes and major creeks and rivers are bordered by wetlands and muskeg occurs sporadically throughout the area. The drier muskegs tested are relatively shallow (less than 100 cm) and overlay sands and silts.

Ice Direction Indicators

Numerous striae were noted on outcrops throughout the area, except at Contact and Sulphide Lakes. Crossing sets of striae were recorded at four locations; the oldest set indicates the ice movement direction to be 190° to 205° and a younger set crosscuts at 212° to 240°, suggesting a readvance slightly more to the southwest. Readings taken from numerous single striae throughout the study area reveal a wide range of directions from 190° to 240°, with the most common direction being 214° to 218°. The local variation in the ice movement direction is probably due to the high relief of the bedrock topography.

Sample Analysis

Till sample analyses comprise geochemical, heavy minerals separation and gold grain documentation. Clay mineralogy will be determined for selected samples. All samples are being subjected to textural analysis.

At present, 134 till samples (including bulk till samples) have been analyzed at the SRC for lead, nickel, cobalt, copper, zinc, silver, arsenic and gold. These samples were wet-sieved to 0.1 mm (-150 mesh) and analyzed by atomic absorption (GFAA).

Heavy mineral separation of the bulk till samples is presently in progress at the SRC using a shaking table and Superpanner. Samples are panned manually to separate the gold grains, which are then described and counted before the concentrates are assayed. The results from the gold grain counts and the geochemical and heavy mineral analyses will be compared to determine the most representative analyses.

These analyses will provide background information for interpretation of mineral distribution, especially gold, in the tills and will aid in the identification of the till unit most effective for exploration sampling.

## Summary and Conclusions

Although few analytical results are yet available, several important preliminary observations can be made:

1) The drift cover in the Sulphide - Hebden Lakes area, although variable due to the rugged topography, is thin in comparison to the Waddy Lake area.

2) Two distinct tills are present: a thin and discontinuous upper brown silty-sand till and a more prevalent lower grey sandy till. Variations in the lithology of the lower till reflect the variations in the local bedrock source, making it the preferred sampling media.

3) In many places the tills have undergone extensive weathering and/or reworking, making till identification and the sampling of the representative material more difficult.

4) Four sets of crosscutting striae indicate an older ice direction of 190° to 205°, which is overridden by a younger readvance flowing in a 212° to 240° direction. The commonest direction of ice flow is 214° to 218°.

5) Glaciolacustrine sediments are found at elevations as high as approximately 419 m. The maximum lake level has been established by the presence of wave-cut terraces and raised beaches at 427 m.

## Acknowledgements

The cooperation of the mining companies in allowing access to their properties is gratefully acknowledged. Special thanks to Saskatchewan Mining Development Corporation for their assistance, cooperation and support during this summer's fieldwork, especially to R. Chapman, G. Curry and S. Eriks for their help and numerous fruitful discussions.

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Schreiner, B.T. (1984): Quaternary Geology of the Precambrian Shield, Saskatchewan; Sask. Geol. Surv. Sask. Energy Mines Rep. 221.

# The Diagenetic-Hydrothermal Metallogenic Model: An Update for Unconformity-Type Uranium and Stratiform Copper Deposits

by David H. Quirt[1] and Jan Hoeve[1]

Quirt, D. and Hoeve, J. (1986): The diagenetic-hydrothermal metallogenetic model: an update for unconformity-type uranium and stratiform copper deposits; in Summary of Investigations 1986, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 86-4.

Under a five-year program, studies of clay mineral host rock alteration around individual Athabasca unconformity-type uranium deposits were complemented by regional studies of clay mineral distribution and diagenesis in the Athabasca Group rocks. Objectives were twofold: firstly, to gain an understanding of the interrelationships between diagenesis, host rock alteration and mineralization and, secondly, to identify diagnostic ore fluid criteria that could be applied in exploration programs to drillhole evaluation.

During the past decade and a half, northern Saskatchewan has emerged as one of the most important uranium districts of the world, following the discovery of spectacular unconformity-type deposits in the Athabasca Basin. Initial discoveries were made at Rabbit Lake and Cluff Lake during the late sixties. Three mines are currently in production: Rabbit Lake (Collins Bay B deposit), Cluff Lake (Claude and Dominique-Peter deposits) and Key Lake (Gaertner deposit). Two deposits have been mined out, the Rabbit Lake deposit and Cluff Lake D zone. At about the same time as in Saskatchewan, unconformity-type uranium mineralization was also discovered in the Northern Territories of Australia. Deposits in the two districts share many characteristics, geological setting, age, host rock alteration, mineralogy and geochemistry, as illustrated by Jabiluka, Ranger and Nabarlek (Ferguson et al., 1980; Ewers et al., 1983; Dahlkamp and Adams, 1981).

Despite their economic significance and a decade of exploration and research, the unconformity-type uranium deposits still constitute a little-understood class of mineralization. In Saskatchewan, early genetic theories assumed an erosional origin for the mineralization, based on the intimate spatial association of ore with the sub-Athabasca paleoweathering profile (Knipping, 1974; Langford, 1974; McMillan, 1977, 1978). Later it became clear that diagenesis of the Athabasca Group red beds had played an important part in the mineralization process (Pagel, 1975a, b; Hoeve and Sibbald, 1976; 1978; Hoeve et al., 1980), while most recently a diagenetic-hydrothermal metallogenetic model was proposed in which ore formation and host rock alteration are directly linked to stages of burial diagenesis and basin evolution (Hoeve and Quirt, 1984). This diagenetic-hydrothermal model calls upon fluid interaction between the Athabasca Group and crystalline basement under conditions of deep burial and highgrade diagenesis during an advanced stage of basin evolution.

A stable isotope study (O, H, C) (Hoeve et al., 1986) of authigenic minerals in Athabasca Group sandstones and of host rock alteration assemblages associated with the deposits has better characterized the fluids involved in the ore-forming process and has tested the diagenetic hydrothermal concept of fluid interaction of sandstone and basement. Included in this study were the Rabbit Lake, Collins Bay, Key Lake, Midwest Lake and McClean lake deposits, which together represent a range of unconformity-type mineralization styles.

The isotopic evidence presented in Hoeve et al. (1986) points to the involvement of two distinct fluids in the hydrothermal process. One is an oxidizing fluid, identified as formation water of the Athabasca Group. The other is a reducing, hydrocarbon-bearing fluid thought to have been generated in the metamorphic basement by reaction of formation waters of the Athabasca Group with graphite contained in metapelitic rocks.

Isotopic and geological evidence indicates that mixing of the two fluids took place above the unconformity at the Midwest deposit and below the unconformity at the Key Lake and Rabbit Lake deposits. This is significant considering that, at Midwest, virtually all ore is above the unconformity, whereas, at Rabbit Lake and Key Lake, most ore is located below the unconformity. For deposits of the Midwest type, mixing of reducing fluids emerging from basement rocks with oxidizing formation waters of the Athabasca Group created a very high redox gradient and a very low pH gradient in the basal sandstone. It appears that two reaction fronts were formed: firstly, a redox front controlling precipitation of ore and secondly, a pH front (or a pK front, if potassium was picked up from the basement by the reducing fluids) controlling the conversion of diagenetic kaolinite into illite.

The isotopic evidence presented in Hoeve et al. (1986) supports the diagenetic-hydrothermal metallogenetic model, presented earlier (Hoeve and Sibbald, 1976, 1978; Hoeve et al., 1980; Hoeve and Quirt, 1984), involving fluid interaction between the Athabasca Group and the crystalline basement, under conditions of deep burial and high-grade diagenesis, during an advanced stage of basin

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evolution. Since the basin floor consists of high-grade metamorphic rocks of inherently low permeability, all such interaction must have been restricted to the vicinity of the unconformity, thus accounting for the observed spatial association of ore deposits with the paleoweathering profile. The model envisages that oxidizing formation waters penetrated below the unconformity, via fault zones, and reacted with graphitic basement rocks to yield reducing fluids containing hydrocarbon and carbon dioxide.

Mineralization is attributed to mixing between the newly generated reducing fluids and oxidizing, metal-bearing formation waters of the Athabasca Group. Depending on characteristics of he plumbing system (where fluid mixing took place), ore was formed just above, at, or just below the unconformity.

On a basin-wide scale, Hoeve and Quirt (1984) documented an intimate relationship between episodes of tectonic reactivation, diabase magmatism, stages of diagenesis and episodes of hydrothermal activity as represented by the first and second stages of mineralization at 1350 to 1250 Ma and 1100 to 1050 Ma, respectively. They proposed that periodic hydrothermal activity at the unconformity may have been regulated by free convection in the basal Athabasca Group aquifer (Manitou Falls Formation), induced by increased heat flow across the basin floor during pulses of tectonism and diabase magmatic activity. They further proposed that positive thermal anomalies at the unconformity, evident as zones of quartz dissolution (Hoeve and Quirt, 1984), directly reflected the presence of graphite-bearing rocks in the basin floor.

The thermal conductivity of graphite is orders of magnitude higher than that of silicates (Clark, 1966; graphite: $400\text{-}1000 \times 10^{-3}$ cal/cm sec$^{o}$C; feldspar: $10 \times 10^{-3}$ cal/cm sec$^{o}$C), making it likely that rocks with even small admixtures of graphite would exhibit greatly increased thermal conductivity, particularly in directions parallel to metamorphic foliation. Tilsley (1980), in a somewhat different context, pointed out that thermal gradients in graphite-rich rocks may be as low as 1 to 2$^{o}$C/km. Thus, for a steeply dipping sheet of graphitic rock extending 1 to 2 km below the Athabasca Group unconformity and for a geothermal gradient estimated at 35$^{o}$C/km (Pagel, 1975a, b), the temperature at the unconformity may well have been in the order of 30 to 50$^{o}$C higher than that of adjacent non-graphitic gneisses. In a situation of increasing heat flow, the significance of thermal anomalies at the unconformity may then have been to lock developing convective cells on graphitic metapelite layers subcropping at the basin floor. The extremely elongate shape of many unconformity-type orebodies (several kilometres long and tens of metres wide and a few tens of metres high) suggests that convective cells in the Athabasca Group aquifer developed into couplets of longitudinal rolls straddling traces of graphitic layers at the unconformity.

Dual flow systems such as envisaged for the unconformity-type deposits may have been driven by a combination of large-scale free convection in the Athabasca aquifer and by small-scale forced convection in the basement (Hoeve and Quirt, 1984). The former would be controlled by the overall heat flow through the basin floor, whereas the latter would depend on the localized extra heat flow channelled through zones of graphitic metapelite.

Fluid mixing between oxidizing and reducing fluids implies hydrodynamic control on ore formation. Isotopic and mineralogical evidence for example, suggests that fluid mixing in ore-forming systems led to the establishment of a distinct redox front. Once established, the front may have remained stationary or migrated. The importance of a stationary redox front in the mineralization process can be inferred from the absence of a zone of secondary hematite in barren alteration haloes and from the fact that all other characteristics of barren haloes appear to be identical to those of ore-bearing haloes, including quartz dissolution, residual clay enrichment, clay alteration and superimposed bleaching (Hoeve and Quirt, 1984).

Thus, within the context of the diagenetic-hydrothermal model, the significance of convection is that it provides for focussed fluid flow, whereas the significance of a stationary redox front is that it provides for focussed precipitation. Since the model is characterized by continuous replenishment of ore constituents, carried by oxidizing formation waters of the Athabasca Group, and by continuous generation of hydrocarbon reductants in the basement, very high grades of mineralization may accumulate over time. The 50 to 100 Ma duration of the intervals of each of the two stages of mineralization in the Athabasca Basin may point to the persistence of favourable and stable hydrodynamic conditions for very long periods of time.

Although at the moment ore-bearing and barren haloes cannot be isotopically distinguished, the $\delta O$-$\delta D$ relationships between hydrothermal chlorites and illites (Hoeve et al., 1986) indicate that isotopic analysis may provide information on the question of whether fluid mixing took place below or above the unconformity. In the former case, mineralization may be expected below the unconformity, and drilling for "root" zones in the metamorphic basement may be a worthwhile strategy. In the latter case of mixing above the unconformity, no basement "roots" are to be expected.

The diagenetic-hydrothermal model is not restricted just to unconformity-type uranium deposits. The origin of stratiform copper deposits has been a longstanding controversy between proponents of syngenetic and epigenetic

mechanisms. In recent years, there has been a movement towards the epigenetic camp with the growing realization that ore metals were introduced after sedimentation in the course of burial diagenesis (Brown, 1971; Bartholome et al., 1973; Bartholome, 1974; Rentzsch, 1974). The early- or late-diagenetic timing of mineralization, however, remains highly uncertain, as does the source of metals. Copper may have been leached from associated red beds during burial and diagenesis or introduced from deep-seated lavas, either during burial metamorphism (Livnat, 1983), or directly during magmatic activity (Annels, 1984). Similar uncertainties surround the transport of ore constituents and the regime of fluid flow.

Stratiform copper deposits in many regions of the world and unconformity-type uranium deposits in the Athabasca Basin share a common geological setting, characterized by thick sections of fluviatile red-bed sandstones and conglomerates sandwiched between a metamorphic basement and a shale-rich marine unit. A potential for mineralization exists not only at the unconformity, but also at the top of the red bed aquifer, if the overlying marine shale is chemically reduced and rich in organics. The stratiform uranium deposits of the Proterozoic Franceville Basin in Gabon and the Permian Lodeve Basin in France provide examples. General aspects of the model can be applied to stratiform copper deposits, and we have proposed (Hoeve and Quirt, 1986) that Proterozoic stratiform copper deposits of the Central African and Michigan Copper Districts, and Permian Kupfershiefer deposits in Central Europe, are examples of diagenetic-hydrothermal mineralization at the top of a red-bed aquifer.

In a broader perspective, ore formation can be considered as an inherent aspect of diagenesis and basin evolution. This has opened the prospect of developing a unified geological model for a spectrum of sediment-hosted, stratiform and unconformity-associated metal deposits, whose unifying feature is an origin that is intimately tied to red-bed diagenesis.

Depending on whether the process of basin evolution and diagenesis goes to completion or is arrested at intermediate stages, a variety of deposits may be generated, ranging from those formed at a low temperature in a shallow environment shortly after burial, to those that formed under conditions of deep burial and high-grade diagenesis during an advanced stage of basin evolution. We have proposed (Hoeve and Quirt, 1986) that giant stratiform copper deposits relate to red-bed copper deposits as unconformity-type uranium deposits relate to sandstone-type uranium deposits. The uranium deposits represent end products and transient intermediate products, respectively, of a process of basin evolution and red bed diagenesis that has gone to completion in the Athabasca Basin. Similar relationships may exist between syngenetic to early diagenetic sandstone lead deposits (Largentiere; Yava) and epigenetic unconformity-related lead deposits (Maubach and Mechernich, Eifel, Germany; Sibley Basin, Ontario; Artillery Lake, Northwest Territories; Otish-Mitassini Basin, Quebec).

The apparently time bound character of Gabon and Lodeve-type stratiform uranium deposits, unconformity-type uranium deposits and stratiform copper deposits (Jacobson, 1975; Robertson et al., 1978; Toens and Andrews-Speed, 1984) suggests that crustal and tectonic conditions allowing the process of basin evolution, red-bed diagenesis and ore formation to proceed to completion have rarely been met in the earth's history. Unconformity-type uranium deposits are primarily restricted to the Middle Proterozoic, whereas stratiform uranium deposits such as in Gabon and Lodeve are known from the Middle Proterozoic and Permian. Stratiform copper deposits appear in the geologic record in early Proterozoic times, but have their main development during the Middle Proterozoic at ca.1000 Ma, with a second major phase during the Permian. The Middle Proterozoic and the Permian were both periods when the land areas on earth were assembled into super continents, creating conditions conducive to the formation of extensive intracratonic basins, to widespread fluviatile terrestrial sedimentation and to the formation of red-beds.

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# Image Analysis Applied to the Investigation of Mineral Exploration Data

by Michel Mellinger[1]

Mellinger, Michel (1986): Image analysis applied to the investigation of mineral exploration data; in Summary of Investigations 1986, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 86-4.

In addition to consolidation of previous work on multivariate analysis of geochemical data (Mellinger, 1986a) and the preparation of a tutorial paper on this subject (Mellinger, 1986b), work was initiated this year on image analysis applied to mineral exploration.

The purpose of this project is the integrated investigation of mineral exploration data over a selected study area by means of raster images, using remote sensing image analysis hardware-software systems. Work has started on a study area in northern Saskatchewan.

The images processed by such a system comprise a set of horizontal lines, each made up of a fixed number of pixels. The images may be either 1) feature images in which the pixels are measurements, as in an airborne geophysical survey; or 2) theme images in which the pixels are numbers representing attributes (class membership), as in a geological map (Fig. 1).

The remote sensing image analysis software provides for the following generic procedures:

- data file input/output and system utilities
- image display on a color (RGB) video screen
- image pre-processing (image statistics, intensity scale manipulation and geometrical transforms)
- feature processing (spatial filtering, e.g. lineament detection and gradient calculations; image enhancement and arithmetic channel combinations)
- pixel classification (for transforming data from up to 16 feature images into a number of classes or themes following various classification methods)
- theme processing (image annotation, spatial smoothing, theme statistics and image-to-image theme comparison).

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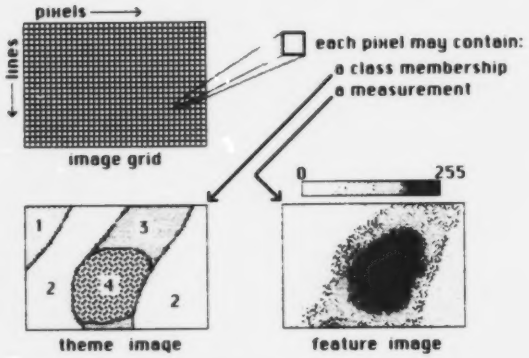


Figure 1 - A raster image and its contents (example of theme image: a geological map showing the distribution of four lithologies; example of a feature image: an aeromagnetic survey re-scaled to 1-byte pixels).

Mineral exploration data can be processed using such software. After all available data from the study area have been digitized (rasterized), each type of data is assigned to one feature or theme channel. Typical data channels for a mineral exploration program include bedrock and surficial geology, structure, geophysics (ground or airborne), geochemistry, topography and vegetation. Any type of data that has been mapped over at least part of the study area can be digitized as an input channel. New feature and theme images can be generated from the input data channels, either from one feature (such as a magnetic gradient derived from total field measurements) or from a combination of channels. In the latter case, for example, pixels classified using a combination of a specific magnetic vertical gradient, the presence of a fault zone within a given distance, and the occurrence within a given rock type. The new image generated this way will integrate information from several input channels in a manner defined by the exploration geologist, and customized to the terrain and economic target being sought.

For the investigation of mineral exploration data, an image analysis system of this type provides for an integrated, flexible and more rapid study of various data types, once the system has been set up and initial data entered.

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RESIDENT GEOLOGIST REPORTS

# Mineral Exploration in Northern Saskatchewan, La Ronge, Reindeer, Wollaston and Athabasca Areas

by A.J. Gracie

Gracie, A.J. (1986): Mineral exploration in northern Saskatchewn, La Ronge, Reindeer, Wollaston and Athabasca areas; in Summary of Investigations 1986, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 86-4.

The estimated provincial level of uranium exploration rose slightly, from $19.5 million in 1985 to $22 million in 1986, for the first time in several years. As a contrast, however, estimated gold exploration expenditures have more than doubled from $7 million to greater than $15 million. Funds have become more readily available, in response to flow-through financing initiatives and, more recently, the new Saskatchewan Stock Savings Plan. Grassroots exploration for platinum group elements escalated. Programs were carried out by Cominco Ltd., Lacana Mining Corporation Ltd. and Silver Lake Explorations Ltd. in areas containing mafic and ultramafic rocks. Esso Minerals Ltd., with a new permit surrounding George Lake, south of Wollaston Lake (Fig. 1) is the only company in the review area with a base metal exploration program. 1986 saw finalization and introduction of The Crown Minerals Act and The Mineral Disposition Regulations, 1986, which replaced those in place since 1961. The new Regulations implement changes outlined under the Mineral Recovery Program, 1984.

The geoscience program funded through the Federal-Provincial Economic Regional Development Agreement 1984-89 (ERDA), was ongoing with a variety of projects: geological mapping and compilation, geochronological investigations, magnetic gradiometer surveys, regional lake sediment surveys, biogeochemistry, mineral deposit investigations and core collection, for the most part devoted toward areas of active gold exploration. Three major all-weather highways to Rabbit Lake, Cluff Lake and Key Lake now give access to northern Saskatchewan, while major improvements to Highway 106 make travel to Flin Flon from La Ronge or Prince Albert much faster.

## Gold

Production will start from the Star Lake 21 zone mine (Saskatchewan Mining Development Corporation (SMDC), Starrex Mining Corporation Ltd., Uranerz Exploration and Mining Ltd. (UEM)) late in 1986. The adjoining Rod zone on the Jolu property (Mahogany Minerals Resources Inc., Canadian Premium Resources Corp.) is scheduled for an underground exploration decline this fall. Placer Development Ltd. may soon announce the results of their exploration work and the plans for

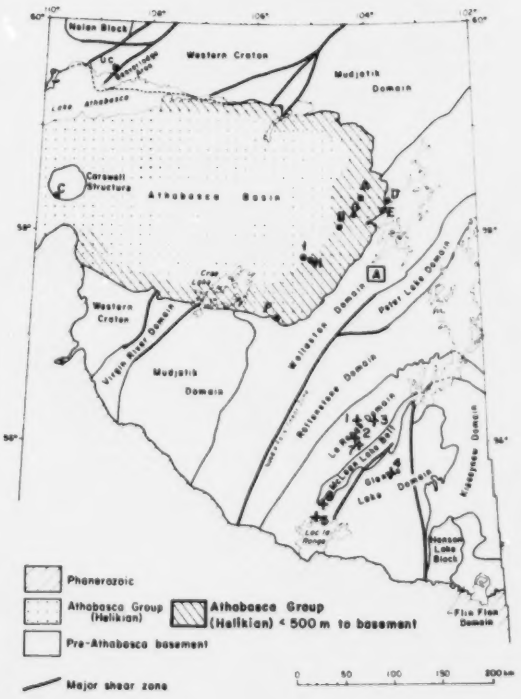


Figure 1 - Northern Saskatchewan in relation to geological domains in the Precambrian Shield. Current uranium mines, potential mines and major exploration locations related to the Athabasca Basin (indicated by dots): (A) Canada Wide Mines Ltd., 'Midwest Lake'; (B) Cigar Lake Mining Corp., Cigar Lake; (C) Cluff Mining Ltd., Cluff Lake; (D) Eldor Resources Ltd., Collins Bay and Eagle Point zones; (E) Eldor Resources Ltd., Rabbit Lake; (F) Key Lake Mining Corp., Key Lake; (G) Saskatchewan Mining Development Corp. (SMDC), Natona Bay, Dawn Lake joint venture; (H) Saskatchewan Mining Development Corp. (SMDC) P2 Zone, McArthur River joint venture; (I) Uranerz Exploration and Mining Ltd., Read Lake joint venture. Current gold mine, potential and major exploration locations (indicated by crosses): (1) Golden Rule Resources Ltd., Tower Lake zone; (2) Mahogany Minerals Resources Inc./Canadian Premium Resources Corp., Rod zone; (3) Placer Development Ltd., Komis and EP zones (Waddy Lake); (4) Placer Development Ltd., Seabee; (5) SMDC, Sulphide Lake joint venture; (6) SMDC, Preview Lake joint venture; (7) Starrex Mining Corp. Ltd./SMDC/UEM, Star Lake Mine.

Current base metal exploration location (indicated by box): A, Esso Minerals Ltd., Spence Lake.

future underground development on the Seabee property.

In late 1985, Golden Rule Resources Ltd., Goldsil Resources Ltd. and SMDC agreed to split up the Tower, Oven and Neyrinck projects into 29 different projects (SMDC News Release, October 28, 1985), thereby unlocking an exploration stalemate on these properties caused by lack of agreement on programs. Under the new division, one of the three major partners has a controlling interest in each of the projects. SMDC, Starrex Mining Corporation Ltd. and UEM have an agreement with Claude Resources Inc. to acquire 66% of the Jojay and Tamar properties for $2 million over four years (George Cross Newsletter, July 23, 1986). These properties may contain the ore necessary to keep the 21 zone mill operating beyond the present three year life expectancy.

Last winter several joint ventures announced drillholes with excellent grades (e.g., at Tower, Preview and Laonil Lakes), indicating a continuing potential for high-grade gold mineralization in the La Ronge and Glennie Lake Domains.

Junior exploration companies still predominate in the La Ronge Domain, although Cogema Canada Ltd., Denison Mines Ltd., UEM, SMDC, Placer Development Ltd. and International Corona Resources Ltd. through its subsidiaries now make an essential contribution.

La Ronge Domain

Drill indicated reserves on the SMDC/Starrex Mining Corp. Ltd./UEM Star Lake property (Fig. 1) are still 208,651 t grading 17.2 g/t (0.5 oz./ton) Au. An 11.5 km all-weather road joins Highway 102 to the new mine site. At the end of August a 1200 m spiral ramp, development on four levels and drilling to define the orebody between levels down to the 130 m level had been completed. In addition, mill construction was over half finished, ahead of schedule and on budget. The mine plans to pour the first gold bar around the turn of the year.

Drill-indicated gold reserves from the Mahogany Minerals Resources Inc./Canadian Premium Resources Corporation Rod zone on the Jolu property have surpassed those on the nearby 21 zone. Bechtel Civil and Minerals Inc. estimates that the Rod contains around 810,000 t of ore grading 20.9 g/t (0./61 oz./ton) Au (Stockwatch, June 2, 1986). Last winter's exploration outlined five new zones on the Rod, although two of these, the B and C zones, contain most of the reserves (Company News Release, April 28, 1986). Mahogany completed an all-weather road to the Jolu property this summer from the Star Lake mine access road. Work on a decline to test the upper levels of the Rod will begin this fall. Royex Gold Mining Corp. have agreed to provide up to $15 million of exploration and development financing for Canadian Premium Resoures Corp. (Stockwatch, Feb. 24, 1986) who may acquire a 50% interest in the property. A Golden Rule Resources Ltd. (40 percent)/Goldsil (40 percent)/SMDC (20 percent) joint venture discovered the PAM zone by testing the northeast extension of the Rod zone on their Blindman property. Here DDH 6 intersected 2.8 m of 27.4 g/t (0.798 oz./ton) Au from 97.08 to 99.88 m (Stockwatch, Feb. 24, 1986).

The Byers Fault is a new target for gold exploration in the La Ronge Domain. The three new drillholes with high-grade gold mineralization announced by Golden Rule Resources Ltd. (Company News Release, April 28, 1986) from their Tower Lake property dramatically demonstrate the potential of this regional structure. DDH T86-22 cut 3 m of 4.8 g/t (0.14 oz./ton) Au from 76 to 79 m, and 23 m of 12.9 g/t (0.38 oz./ton) Au from 98 to 121 m. Included in the second intersection, known as the PAT zone, is a 3 m interval, from 115 to 118 m, assaying 59.4 g/t (1.73 oz./ton) Au. The gold mineralization is in sheared granodiorite quartz-eye porphyry which intrudes metavolcanic rocks adjacent to the Byers Fault. The property is owned jointly by Golden Rule Resources Ltd. (37.5 percent), Goldsil Resources Ltd. (37.5 percent), SMDC (20 percent) and Comaplex Resources International Ltd. (5 percent).

The Dickens Lake project just north of Otter Rapids, in which Draw International Resources Corp. will earn an interest from SMDC, also covers a wide zone of alteration and mineralization linked to an east-west regional fault (Stockwatch, April 14, 1986). Assays from surface samples have reached 57.3 g/t (1.67 oz./ton) Au. In the Sulphide Lake area, an SMDC/UEM/Windora Minerals Ltd. joint venture is evaluating Pap Lake gold zones controlled by shears in gabbro-diorite and felsic volcanics. Concordant quartz veins with pyrite, arsenopyrite and free gold are present in the shear zones. Consistently good gold values were obtained in shears in eight out of ten holes drilled last winter (Stockwatch, May 30, 1986). DDH PR 86-18 cut 0.5 m of 20.5 g/t (0.60 oz./ton) Au from 1.1 to 1.6 m, 0.8 m of 3.8 g/t (0.11 oz./ton) Au from 6.4 to 7.2 m, and 17.1 m of 12.2 g/t (0.36 oz./ton) Au from 35.5 to 52.6 m. New drill programs could expand the PAP zones, although the size of the enclosing mafic bodies is limited. Results at Ramsland Lake on the same project have been less predictable so far. Four out of ten drill holes gave significant gold values last winter (Stockwatch, May 30, 1986).

The Sulphide Lake Galena, Studer A, B and F zones make a stratiform gold target, where the gold is linked to lean iron formation (Coombe, 1984), which is a formational conductor running along a volcanic/metasedimentary contact. Claimed reserves are 907,180 t grading 2.3 g/t (0.07 oz./ton) Au in the A and B zones. The A and B Zone figures include 158,757 t at 7.6 g/t (0.22 oz./ton) Au. An additional 16,329 t at 14.4 g/t (0.42 oz./ton) Au is

recognized in the C zone located in close proximity to a second conductive zone (Stockwatch, Feb. 21 and April 18, 1986). The SMDC, Denison Mines Ltd. and Torex Minerals Ltd. joint venture added to the tonnage on the A and B zones with sixteen new holes last winter (Stockwatch, April 18th), but did not improve the grade; however, improved grades and possibly also tonnage were indicated for the C Zone.

### Glennie Lake Domain

Placer Development Ltd. have not released any definite information about ore reserves or future plans for the Seabee property. The company's drill programs should have added to previously estimated proven and probable reserves in the 2, 5, 11 and 14 zones of 562,454 t grading 18.2 g/t (0.53 oz./ton) Au uncut, or 11.0 g/t (0.32 oz./ton) Au cut to 34.3 g/t (1.0 oz./ton) Au to a depth of 183 m (Gummer, 1985).

The winter drill program sought to extend the shear zones which host vein systems 2 and 5 to depth and out under Laonil Lake (Northern Miner, April 28, 1986). Diamond-drill hole 161 crossed two excellent gold intersections 244 m west of the mineralized section of zone 5 in the same major shear structure. Recorded ore 12.3 m (true width 7.9 m) of 17.4 g/t (0.51 oz./ton) Au from 65 to 78.3 m and 3.2 m (true width 2.06 m) of 14.2 g/t (0.41 oz./ton) Au from 120.5 to 123.7 m. Placer also carried out work to advance other drill targets on the Seabee property and the surrounding three claim blocks.

Cogema Canada Ltd. worked on their permit to the west, and six junior companies ran preliminary grassroots programs this summer to the east and south. In the wider area Carina Mineral Resources Corp. is also active on MPP 1132 surrounding Brownell Lake.

### Other Areas

The level of gold exploration north of Lake Athabasca remained low. Possible volcanics to the north of Stony Rapids still offer an opportunity for grassroots exploration in a neglected area. These rocks lie within the Western Craton which here consists of retrogressively metamorphosed granulite facies terrain. Because Highway 105 is now within 130 km of Black Lake and Stony Rapids, the area is now somewhat more accessible. Colchis Resources Ltd. began work on its properties in August 1986 and Cominco Ltd. staked four new claim blocks for gold in the Grease River area.

Elsewhere Claude Resources Inc. took out a new permit on the Virgin River Domain and Rex Silver Mines Ltd. completed some work on their old permit in the Mudjatik Domain. Both permits cover rocks interpreted as volcanic.

## Uranium

Uranium exploration was mainly in the eastern Athabasca Basin and the Carswell Structure, areas which contain producing uranium mines at Key Lake, Rabbit Lake-Collins Bay and Cluff Lake and all of the major undeveloped deposits including the massive Cigar Lake Mining Corporation (CLMC) orebody at Cigar Lake. Work on the Cigar Lake shaft and the development of two levels will begin next year (Northern Miner, Sept. 1, 1986). Uranium exploration continued where the Athabasca Group exceeds 500 m in thickness, although no work was carried out in the centre of the basin or along its northern and southwestern perimeters.

### Athabasca Group Perimeter

Production at Key Lake totalled 4,270 t U in 1985 (SMDC Annual Report, 1985) and recoverable reserves as of December 31, 1985 were 67,000 t U. This operation is the world's largest producing uranium mine. The Gaertner orebody will be mined out by year end and work has already started to develop the Deilmann orebody. Eldorado Resources Ltd. produced only 824 tonnes U at Rabbit Lake in 1985. A $100 million development and expansion program completed in 1985 will return the Rabbit Lake mill capacity to a minimum of 2,000 t U per year (Eldorado Annual Report, 1985). Milling of the Collins Bay ore where Eldorado has reserves of 12,000 t U required the installation of new mill circuitry which was commissioned in the last quarter of 1985.

Exploration programs still concentrate on the detection of conductor- and/or fault-related unconformity deposits using the Key Lake model as a basis. Geophysical techniques have been used to detect basement conductors since the discovery of Key Lake in 1975, and sites of known uranium mineralization are now quite numerous. However, in proximity to Key Lake itself, despite the experience gained over ten years plus new money and expertise from companies with farm-in agreements such as Minatco Ltd., Central Electricity Generating Board (Canada) Ltd. (CEGB), Denison Mines Ltd. and UEM, no venture has defined another commercial deposit of uranium.

New mineralized holes continue to be drilled. For example, SMDC found unconformity mineralization on their Dawn Lake venture at Natona Bay on Waterbury Lake, which is on strike and approximately 20 km northeast of Cigar Lake (Fig. 1). Diamond-drilling cut values of up to 4.7 percent U over 5.3 m under 260 m of sandstone (SMDC Annual Report, 1985). SMDC has also reported sandstone-hosted mineralization from the BJ location on the McArthur River project. At BJ, diamond-drilling found up to 2.7 percent U over 4.0 m at a depth of 400 m. One of these new mineralized holes may lead to the discovery of a new uranium orebody comparable to Cigar Lake.

### Athabasca Group Interior

The Cigar Lake Mining Corporation was formed by SMDC (50.57 percent), Idemitsu Uranium Exploration Canada Ltd. (12.875 percent), Cogema Canada Ltd. (32.625 percent) and Corona Grande Exploration Corp. (3.75 percent) in May 1985. The Corporation wishes to develop the huge reserves of ore in the Cigar Lake deposit for commercial production by the first part of the next decade. CLMC must demonstrate a feasible mining method and design and construct a 4,600 t U/yr mill. To this end the company has announced a test mining schedule, beginning in 1987, which will entail sinking of a 488 m shaft and development of two levels above and below the orebody (Northern Miner, Sept. 1, 1986).

Reserves are 110,000 t U grading 11.8 percent U in the main zone. Inferred reserves at the western end of the deposit are 38,500 t U grading 3.82 percent U. These figures indicate that the Cigar Lake orebody, which lies below Athabasca Group sandstones at an average depth of 430 m, may be double the size of the Key Lake orebody. This spectacular find, together with improved geophysical methods and the lack of new discoveries in the immediate area of Key Lake, has prompted other companies to test deep basement targets at 500 m or more below surface.

Exploration methods are the same in the Athabasca Group interior as in the deeper parts of the perimeter area, although exploration is clearly more difficult and costly. The increased interest observed in 1984-85 was maintained this year, in part due to improved geophysical methods (e.g., large loop UTEM and Pulse EM), which can outline conductors at much greater depth. Several companies ran new airborne and ground geophysical survey programs and three completed major drill programs. Cogema Canada Ltd. attempted to prove an orebody around DDH CLC5-011 which cut unconformity mineralization on the Close Lake venture south of Blixrud Lake (Imperial Metals News Release, April 22, 1985). SMDC tested sandstone mineralization on the P2 location 8 km northwest of the BJ prospect on the McArthur River project. Core from P2 assayed up to 1.19 percent U over 7.3 m at a depth of 525 m (SMDC Annual Report, 1985). UEM, in joint venture with SMDC and Kerr Addison Mines Ltd., continued to drill close to the P2 location on the Read Lake property (Fig. 1).

### Carswell Structure

Cluff Lake Mining, owned by Amok Ltd./Ltee. (80 percent) and SMDC (20 percent), produced 835 t U in 1985 from the Claude, OP and Dominique-Peter zones. Production in 1986 is from the Claude open pit and the Dominique-Peter underground mine where an undercut and fill method has been successfully introduced. Recoverable reserves as of December 31, 1985 were 32,400 t U. The company also plans to extract gold and uranium from highly radioactive tails from the Phase 1 mining of the D zone.

The Carswell Structure uranium deposits are of unconformity type and, for the most part, related to mylonite zones surrounding gneiss domes at the contact of Peter River and underlying Earl River Gneisses (Laine, Alonso and Svab, 1985).

### Crystalline Basement

In general, companies have continued to show little interest in the uranium potential of rocks outside of the Athabasca Group Basin, although Eldorado Resources Ltd. has identified combined reserves at Eagle North and South of more than 50,000 t U, significantly in excess of those in the Collins Bay zones. Geological reserves at Eagle South are more than 30,000 t U while those at Eagle North are now estimated at 20,000 t U averaging 2.2 percent U based on a cutoff grade of 0.42 percent U.

## Platinum Group Elements

Exploration for platinum group metals is still in its infancy in the province, although the level is increasing. Lacana Mining Corp. and Cominco Ltd. have grassroot programs in the Peter Lake Domain, a region dominated by locally layered mafic bodies cut by later granites. Colchis Resources Ltd. and Silver Lake Resources Ltd. are examining mafic intrusive prospects in the Western Craton. American Platinum and others are actively searching in the Rottenstone Domain for ultramafic-mafic bodies similar to that which hosted the Rottenstone Mine. This deposit was reported to contain 45,000 to 55,000 t of ore grading 2 percent Ni, 2 percent Cu, 7.5 g/t (0.22 oz./ton) Pt and 5.1 g/t (0.15 oz./ton) Pd (Northern Miner, April 15, 1965). Intrusions in the La Ronge Domain are also being examined.

## Base Metals

Exploration for base metals is limited to a very small program on the Esso Minerals Ltd. permit in the Spence Lake area of the Wollaston Domain.

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# Mineral Exploration Activity in the Southeastern Part of the Northern Mining District

by J.G. Pearson

Pearson, J.G. (1986): Mineral exploration activity in the southeastern part of the Northern Mining District; in Summary of Investigations 1986, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 86-4.

Mineral exploration during the past year has concentrated on the search for gold deposits in the Flin Flon Domain and in the southern Kisseynew Domain. Most of this exploration has been in the areas of known gold mineralization in proximity to Flin Flon and Amisk Lake. Preliminary investigations are taking place in the southern Kisseynew Domain, and targetted on hornblende-rich mafic gneisses considered to be volcanic in origin.

The focus for base metal exploration has shifted from exposed metavolcanic rocks of the Flin Flon and Glennie Lake Domains to their southerly extensions under Phanerozoic cover. As well, there has been a move from traditional exploration for volcanogenic massive sulphide deposits to the search for intrusive ultramafic-hosted nickel deposits of the Namew Lake type, discovered by Hudson Bay Exploration and Development Co. Ltd. (HBED) last year.

During the past year 945.2 km$^2$ (233,570 acres) were staked as claims and claim blocks in the area covered by this report (NTS 63 K, L, M). Much of this area (approximately 50 percent) was staked in the conversion of permits to claim blocks. This is a significant drop in staking activity from the previous year when 1741.7 km$^2$ (430,375 acres) were staked and 155.5 km$^2$ were taken out in permits. During the past year 2539.9 km$^2$ (626,397 acres) in claims, claim blocks, leases and permits lapsed.

## Gold

Esmeralda Minerals conducted a 26 km VLF-EM survey to evaluate ground they hold on strike with the new Tartan Lake Deposit currently being brought into production by Granges Exploration Ltd.

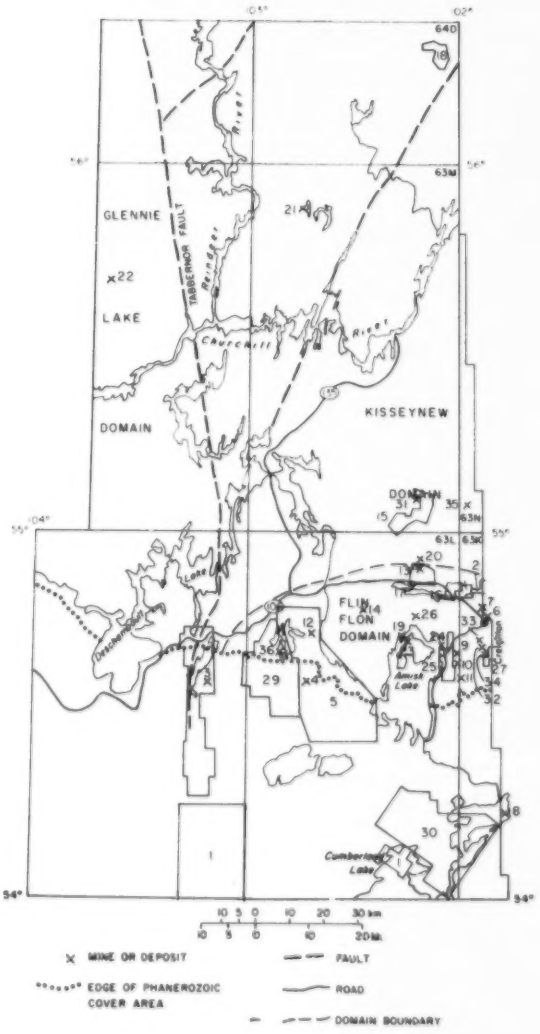


Figure 1 - Location of the southeastern part of the Northern Mining District showing present and past producing mines, deposits and areas of active exploration. Areas are designated by operator of the project only: Cominco (1); Esmeralda Minerals Inc. (2); Granges Exploration, Bigstone Deposit (3); McDermott Lake (4); Balsam (5); Hudson Bay Exploration and Development Co. Ltd., Flin Flon Mine (6); Callinan zone (7); Namew Lake deposit (8); Flexar Mine (9); Birch Lake Mine (10); Coronation Mine (11); Mal zone (12); Tyrrell Lake zone (13); Fon zone (14); Homestake Mineral Development Co., Wildnest Lake (15); Nesootao Lake (16); Tyrrell Lake (17); Kamuchawie Lake (18); Kenton Natural Resources Corp., Monarch Mine (19); Maverick Mountain Vass Lake zone (20); A.L. Parres Ltd., Mukoman Lake zone (21); Placer Development Co. Ltd., Seabee deposit (22); Saskatchewan Mining Development Corp., Laurel Lake zone (23); Amisk Sysdicate (24); Denare Beach (25); Graham Mine (26); Phantom Lake - Boot Lake (27); Nesootao Lake (28); Hanson Lake (29); Namew Lake (30); Stall Lake Mines, Schott Lake zone (31); Vista Mines Inc., Rio Mine (32); Newcor Mine (33); Henning-Maloney Mine (34); Wapa Minerals, Dolly occurrence (35); Western Nuclear Mines Ltd., Hanson Lake Mine (36).

HBED carried out two gold exploration programs in the Flin Flon area, one in the Kisseynew Domain northwest of Flin Flon and the other in the Flin Flon Domain south of Flin Flon. The program in the Kisseynew Domain consisted of the following surveys: 28 km of Maxmin II EM, 9 km of VLF-EM, 37 km of magnetometer, geological mapping and a humus soil geochemical survey. In the Flin Flon domain HBED carried out a program of line-cutting and a 38 km VLF-EM survey to evaluate known gold showings.

Homestake Mineral Development Co. conducted several exploration programs for stratabound gold mineralization in the Kisseynew Domain. This program began with a 660 km airborne magnetometer and VLF-EM survey in the Wildnest Lake area and followed up with reconnaissance mapping and lithogeochemical programs at Wildnest Lake, Tyrrel Lake and Kamuchawie Lake. In addition, humus geochemistry and VLF-EM surveys were conducted over specific target areas.

Kenton Natural Resoures Corporation has acquired the former Monarch Mine, the original, 1913 discovery of gold mineralization in the Flin Flon - Amisk Lake area, located in the West Channel of Amisk Lake. During the past summer Kenton has undertaken a program that includes VLF-EM and magnetometer surveys, soil geochemistry, trenching and diamond-drilling. The drill program consisted of seven holes, five of which tested the mine horizon. The remaining holes tested a newly discovered litho and soil geochemical anomaly south of the mine horizon. Production from this deposit during 1937 and between 1940 and 1942 yielded 4882.36 ounces of gold and 837.06 ounces of silver from 5821.0 tons of ore (Byers and Dahlstrom, 1954).

The Saskatchewan Mining Development Corporation (SMDC) undertook several gold exploration programs in the Flin Flon Domain and one program in the Kisseynew Domain. In the latter geological mapping and lithogeochemical sampling were carried out at Melgurd Lake. This was designed to determine the cause of a gold in lake sediment geochemical anomaly identified in GSC Open File 1129.

On the Laurel Lake North zone, the corporation drilled 4000 m in 34 holes to delimit previously discovered gold mineralization (Pearson, 1985). This program was supplemented by detailed VLF-EM and IP surveys and by biogeochemical sampling. Elsewhere in the West Channel of Amisk Lake, 10 holes (1000 m) were drilled on geophysical and geochemical anomalies. In the east Amisk Lake area, a further 5 holes (500 m) were put down to evaluate the Amisk Syndicate occurrence and a biogeochemical survey, was carried out. At Denare Beach, also on Amisk Lake, there was a preliminary gold exploration program of reconnaissance geological mapping and lithogeochemical sampling, and on ground surrounding the Graham Mine north of Amisk Lake, reconnaissance mapping and lithogeochemical sampling. In immediate proximity to the mine detailed geological mapping, lithogeochemical, biogeochemical and soil geochemical surveys were conducted over a 10 km grid and existing trenches were channel sampled.

Over the past two years SMDC has acquired a significant land position covering several gold occurrences as well as two small "mines" in the Phantom Lake - Boot Lake area south of Flin Flon. During the past year, there were 115 km of line-cutting on this property, 102 km of magnetometer and VLF-EM surveys, geological mapping and a lithogeochemical survey. In the Nesootao Lake area, on ground that is considered to be an extension of the Granges' Tartan Lake deposit, exploration programs included geological mapping, lithogeochemical sampling and 105 km of VLF-EM and magnetometer.

Vista Mines Inc. has acquired the former Flin Flon Mines Rio mine, mill and surrounding properties, which include the former Henning-Maloney and the Newcor Mines. Vista plans a major diamond-drill program to evaluate each of these deposits, concentrating initially on the Rio deposit. Underground exploration of the Rio deposit is also planned.

Base Metals

Cominco Ltd. completed 980 m of drilling in three diamond-drill holes and about 30 km of ground EM and magnetometer surveys on MPP 1144 and 1151 as a follow-up to earlier airborne and ground geophysical work. The company also conducted about 55 km of ground EM and magnetometer surveys over claims in the Cumberland Lake area. Additional geophysical work and possibly diamond-drilling are expected in both regions in 1987.

Granges Exploration Ltd. was active in three drilling projects in the Flin Flon Domain for volcanogenic base metal deposits. In the Balsam Lake area the company drilled 968 m in seven holes to test previously discovered electromagnetic conductors. On the MacDermott Lake zone discovered last year, 23 holes (3265.9 m) were drilled to outline the size and grade of the deposit and in the Bigstone - Limestone Lake area 15 holes (1461 m) were put down to test electromagnetic anomalies.

HBED carried out a program of line-cutting, 180 km of MaxMin II EM and magnetometer surveys to investigate the area to the west of the Namew Lake nickel-copper deposit. One anomaly was drilled. To the north 697 m of diamond-drilling were completed to test electromagnetic conductors under an HBED-operated joint venture with SMDC. In the area west of Flin Flon, 2104 m of diamond-drilling were completed to further investigate a known zinc deposit.

In the Hanson Lake area, SMDC conducted a winter exploration program which included diamond-drilling and geophysics. Twelve holes (2164 m) were drilled to test eight targets and four of these holes were evaluated with down-hole pulse EM. Additional exploration included 92 km of Maxmin II EM and magnetometer surveys on four grids. In the Namew Lake area SMDC, in joint venture with Esso Minerals Canada, did 220 km of Maxmin II and magnetometer surveys on 11 grids, in the search for "Namew Lake type" nickel-copper and massive sulphide deposits.

Acknowledgements

I wish to thank Al Scarfe for compiling the claim staking statistics.

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SOUTHERN STUDIES

# The Dawson Bay Formation (Devonian) in Southeastern Saskatchewan

by D.M. Lane

Lane, D.M. (1986): The Dawson Bay Formation (Devonian) in southeastern Saskatchewan; in Summary of Investigations 1985, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 86-4.

This study, commissioned in April 1986, entails mapping of the subsurface Middle Devonian/Dawson Bay Formation in the southeastern Saskatchewan oil-producing area (Fig. 1).

Previous departmental studies of Dawson Bay strata have been restricted to the potash-producing areas of the province. The current study overlaps a portion of a previous report published by the author in 1959.

The most current work on the Dawson Bay strata of Saskatchewan is a report by Dunn (1982).

## Progress to Date

1) The majority of available reference material has been assembled and read.

2) Preliminary working data have been assembled and compiled for most of the 250 wells

Figure 1 - Location of the study area

penetrating the Dawson Bay strata in the study area.

3) Preliminary work maps are currently being prepared.

General Stratigraphy

The Middle Devonian Dawson Bay Formation immediately overlies halites of the Prairie

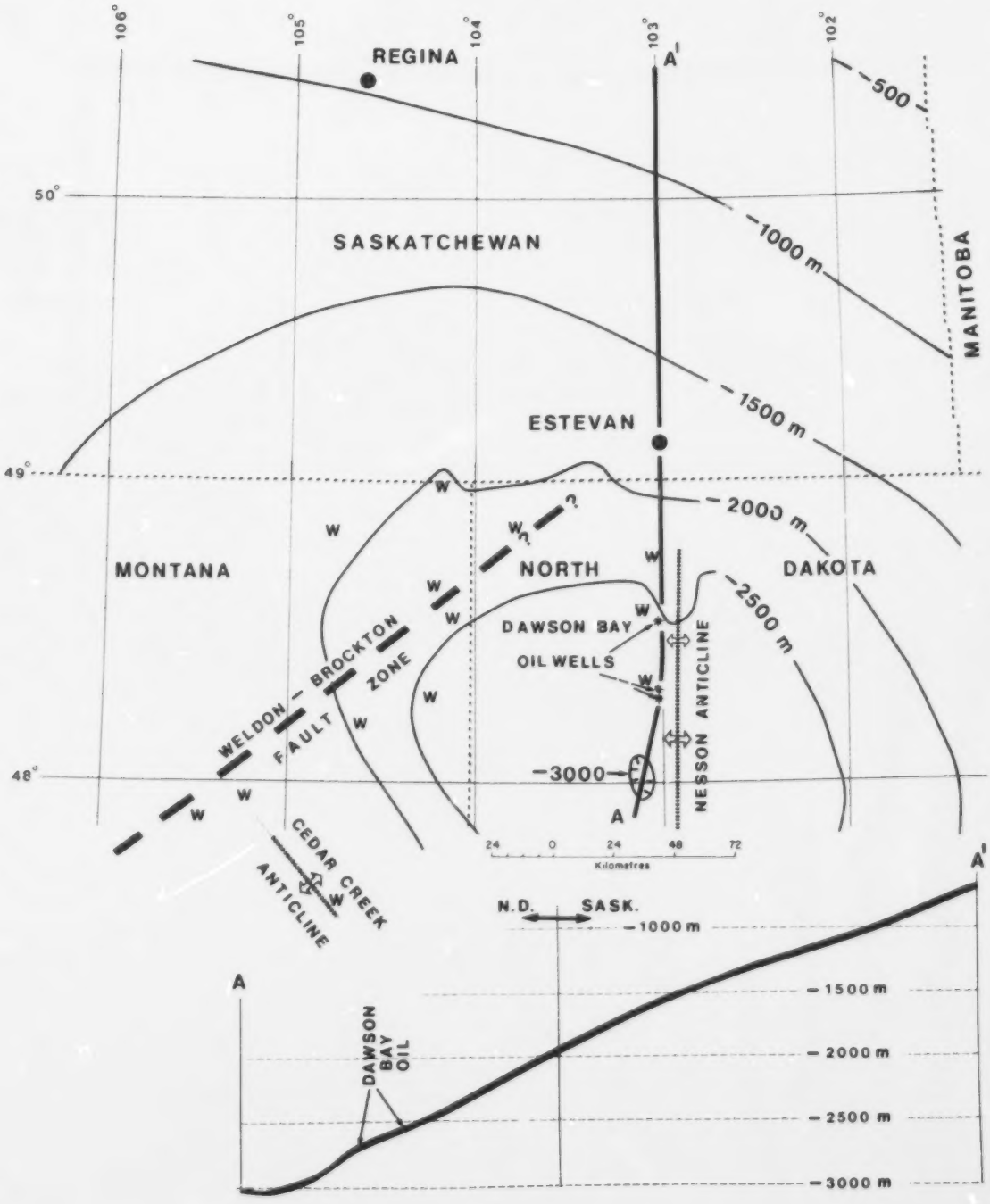


Figure 2 - Regional structure map and section.

Evaporite Formation in the major portion of the study area. In the western portion of the study area, the formation overlies the insoluble residue of the Prairie Evaporite or, in the extreme southwest corner of the area past the depositional edge of the Prairie Evaporite, it directly overlies the thin basin margin carbonates of the Winnipegosis Formation.

The formation is directly overlain by the basal unit of the Souris River Formation (First Red Beds).

The Dawson Bay Formation maintains a thickness of 25 to 65 m (80 to 210 ft.) in the study area.

Regional Structure Map and Section (Fig. 2)

The structure contour map of the Dawson Bay shows the top of the formation rising from its maximum subsea depth of over 3000 m below sea level in northwestern North Dakota to less than 500 m below sea level in the northeastern portion of the study area. The maximum depth reached in southern Saskatchewan is slightly over 2000 m below sea level near the northwest corner of North Dakota.

The structure contour map shows the general location of the major structural features that may control oil migration from deeper formations, as well as the location of production of Type 1 (Winnipeg) oil (Dow, 1974), indicated by a (W) on the map. The location of the three wells producing Dawson Bay oil on the Nesson Anticline are shown on both the map and section A'-A'.

Table 1 summarizes the general lithology of the Dawson Bay Formation in the study area and in the potential hydrocarbon source area immediately south of the study area. The five lithofacies of Pound, 1985 are laterally persistent in North Dakota, as are equivalent lithofacies in the current study area.

Table 1 - Lithology of the Dawson Bay Formation in Southeastern Saskatchewan (Lane, 1959) and North Dakota (Pound, 1985).

(Upward depositional order)

| Saskatchewan (Lane, 1959) | North Dakota (Pound, 1985) |
|---|---|
| Phases | Lithofacies |
| 7) Halite | - Not developed |
| 6) Gastropod - bituminous and pelletoidal limestones, dolomitic anhydrite (fore-reef and basin facies) | F) Cryptalgal mudstones and boundstones<br>E) Gastropod-ostracod mudstones<br>D) Gastropod-ostracod-brachipod-echinoderm wackestones and mudstones |
| 5) Stromatoporoid - stromatoporoidal limestones and/or saccharoidal DOLOMITES (BIOSTROMAL FACIES) | C) Stromatoporoid boundstones wackestones and mudstones |
| 4) Coral-brachiopod - crypto-crystalline light coloured limestone containing crinoid ossicles, brachiopods and simple corals (normal marine facies)<br>3) Lingula - Microgranular carbonates (shallow water lime mud facies) | B) Brachiopod-echinoderm mudstones and wackestones |
| 2) Green shale<br>1) Red shale | not included by Pound |

Pound (1985) indicated that three wells produced more than 44,670 $m^3$ (281,000 bbls.) of oil during the period 1980 to 1984 (inclusive) from the Dawson Bay Formation. These wells produce from a structural trap, associated with the Nesson Anticline, in Temple Field, Williams County, North Dakota. Core from the most productive well, Pederson #1 (SW SW Section 30 Range 98 W Township 129 N) located some 80 km due south of Estevan, suggests that extensive and recurrent fracturing is common in the Temple Field and that the anticlinal, structural trapping mechanism in Williams County may be supplemented by halite-filled porosity and argillaceous lithologies present in the basal Souris River Formation. He has further suggested that hydrocarbons may be trapped beneath the replacive anhydrite in his lithofacies F (Cryptalgal mudstones and boundstones) associated with depositionally thin isopach anomalies in Bottineau and adjacent counties.

Hydrocarbon shows from the Dawson Bay Formation in Saskatchewan include recovery of 20 m (65 feet) of oil and salt water cut mud from DST #6 in the Newman No. 12 (Lsd 12-29-2-2W2) well.

The present study will identify the potential areas for hydrocarbon entrapment in the study area, identify possible hydrocarbon migration paths and provide structural data that may assist in the structural and depositional interpretation of the overlying sediments.

## Preliminary Findings

Preliminary findings show that the Dawson Bay carbonates (i.e., excluding the Dawson Bay evaporites and the basal red and green shale units) are remarkably persistent in lithological character and thickness where they were deposited over halites of the Prairie Evaporite. Local thinning of the Dawson Bay carbonate unit occurs over known Winnipegosis carbonate buildups within this area.

Preliminary findings suggest the presence of at least two types of collapse structures due to the removal of up to 130 m of Prairie Evaporite halites: 1) "block or imbricate" collapse wherein the Dawson Bay Formation is possibly repeated by reverse faulting and 2) brecciation of the Dawson Bay and overlying Souris River Formation in areas of local or "spot" solutioning of the Prairie Evaporite.

Table 2 provides a rough summary of Devonian and Lower Paleozoic wells from which oil has been produced up to the end of 1984 for southeastern Saskatchewan (the current study area), northwestern North Dakota and northeastern Montana.

Table 2 - Wells Producing Oil from Devonian and Lower Paleozoic Strata in Southeastern Saskatchewan, Northwestern North Dakota and Northeastern Montana.

| Formation | Number of Wells | | |
|---|---|---|---|
| | NE Montana | SE Saskat-chewan | NW North Dakota |
| Bakken | 1 | 26 | 5 |
| Torquay | 0 | 0 | 2 |
| Birdbear | 51 | 16 | 3 |
| Duperow | 5 | 0 | 45 |
| Souris River | 1 | 0 | 1 |
| Dawson Bay | 0 | 0 | 3 |
| Winnipegosis | 12 | 1 | 10 |
| Interlake | 0 | 0 | 4 |
| Stonewall | 7 | 0 | 4 |
| Red River | 144 | 3 | 55 |
| Deadwood | 0 | 0 | 2 |

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## Development of a Depositional Model for the Oil-Prone Jurassic Section in the Wapella - Moosomin Area, Southeastern Saskatchewan

by L.K. Kreis

Kreis, L.K. (1986): Development of a depositional model for the oil-prone Jurassic section in the Wapella-Moosomin area, southeastern Saskatchewan; in Summary of Investigations 1986, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 86-4.

A preliminary study of the Wapella-Moosomin area by the author, published in the 1985 Summary of Investigations, disclosed the geographic areas and stratigraphic interval in which Jurassic production is found. Particular attention was paid to the Wapella pool. The investigation concluded that, because no detailed geologic study of the area had yet been done and in view of the recent Jurassic

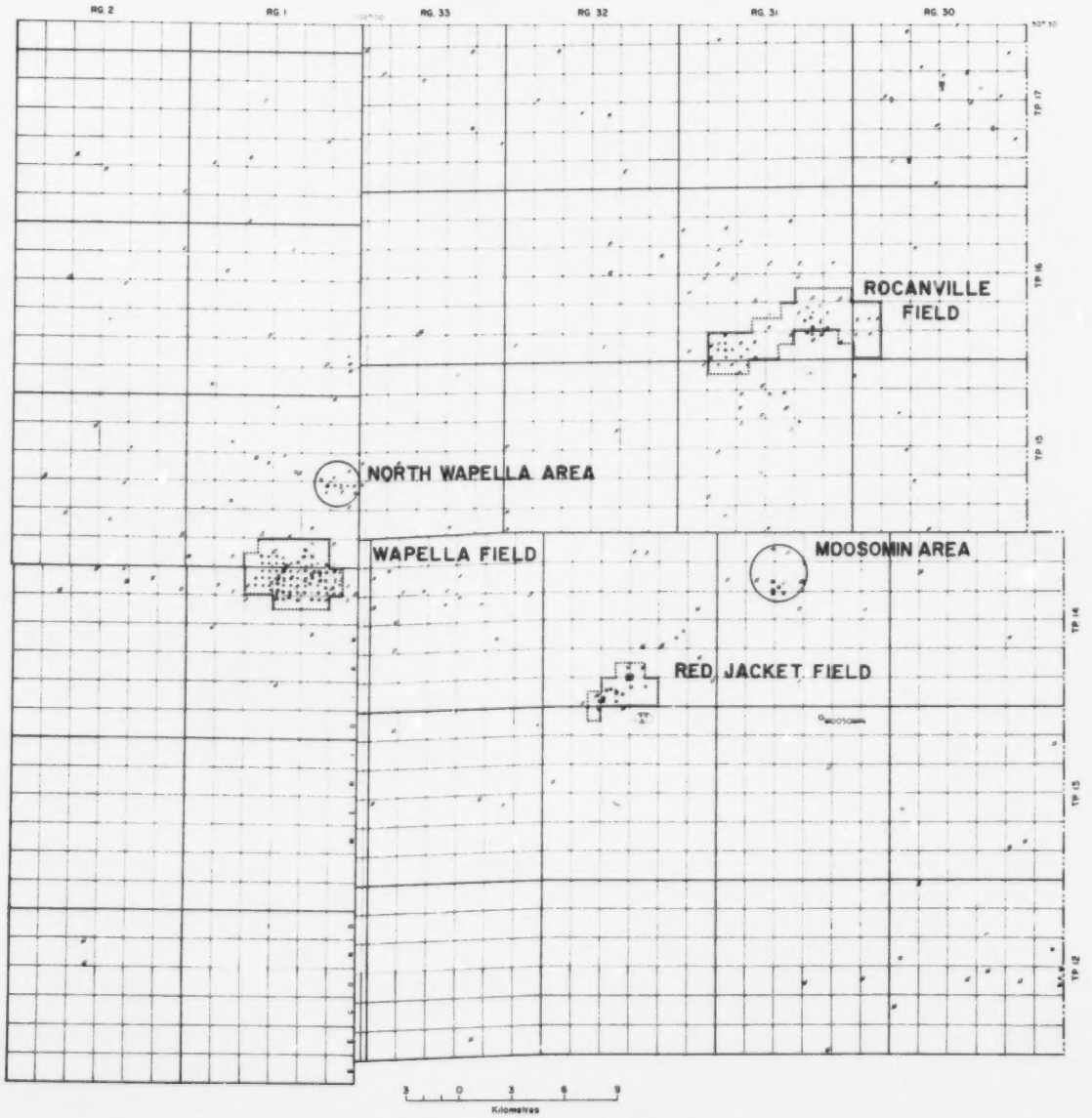


Figure 1 - Location of study area.

discoveries in the Moosomin and Red Jacket localities, the region has greater potential than was previously believed.

Consequently, work on the oil-prone subsurface Jurassic section in the Wapella-Moosomin area was initiated as a full-scale department project in June 1986. The focus of this study will be on the development of a depositional model for the oil productive portion of the undifferentiated Jurassic section in the study area (Figs. 1 and 2). At present, Jurassic oil production is found in the Wapella and Red Jacket fields and miscellaneous production is observed in the North Wapella and Moosomin localities (Fig. 1).

Some 360 wells are present in the study area and all will be examined for their geophysical log and available core information. Well cuttings will also be used if necessary.

In this report, the term "field" is used to describe the surface limits of an oil-producing area where production may be from several pools. The term "pool" will refer to a discrete stratigraphic accumulation of oil.

A bibliography for the study area is included.

## Geology and Stratigraphy

The section to be studied is generally characterized by a sequence of silts, sands and shales. Facies changes in the section have caused it to differ markedly from the type sections. This makes correlation difficult. It appears to be stratigraphically equivalent to the Jurassic Gravelbourg and Shaunavon Formations (Francis, 1956).

The study will be primarily concerned with all sediments below what is informally known by workers in the area as the Jurassic (Shaunavon?) shale marker down to the top of the Watrous anhydrite, also of Jurassic age (Fig. 2). Where the Upper Watrous is not present by way of nondeposition and possibly erosion, the Jurassic section of interest rests unconformably on the Souris Valley Beds of the truncated Mississippian surface. All known Jurassic production in the study area comes from this stratigraphic interval.

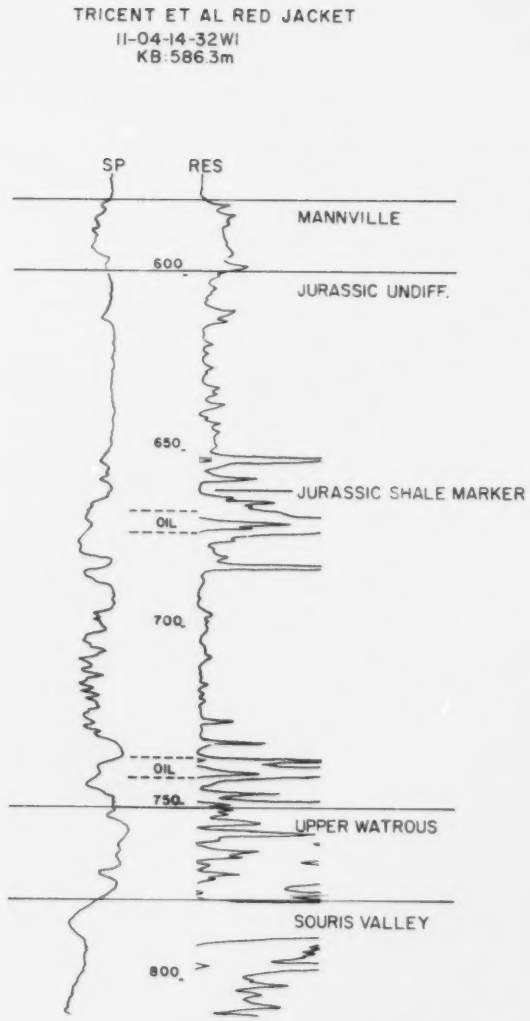


Figure 2 - Section showing stratigraphic interval being studied (indicated by shading). Note that two separate oil-productive reservoirs exist below the Jurassic (Shaunavon?) shale marker in this well.

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# The Clay Rocks in the PCS Mining Limited, Cory Division Potash Mine, Saskatchewan

by C. Boys[1], F.F. Langford[1], R. Renaut[1] and T. Danyluk[2]

Boys, C., Langford, F.F., Renaut, R. and Danyluk, T. (1986): The clay rocks in the PCS Mining Limited, Cory Division Potash Mine, Saskatchewan; in Summary of Investigations 1986, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 86-4.

A classification of the rocks in clay seams over a stratigraphic interval of about 8 m at PCS Mining Limited, Cory Division potash mine has distinguished twelve categories of clay rock.

This paper results from a continuing study of the main potash-bearing zone in the Patience Lake Member of the Middle Devonian Prairie Evaporite Formation at PCS Mining, Cory Division. The mine is located about 8 km west of Saskatoon. The intent is to classify rocks from the "clay" seams that occur in a stratigraphic interval of about 8 m, which includes the potash ore zone (Fig. 1). "Clay" is the mining term for insolubles and, unless referring to specific clay minerals, is used here in this way. The aim is to provide a basis for detailed correlation and understanding of the clay seams, which may help to provide indicators of anomalous ground (cf. Baar, 1974; Mackintosh and McVittie, 1983) in advance of mining. The classification presented herein applies to the clay seams and not to potash rocks containing disseminated clay.

## Clay Rocks

Insolubles occur in the evaporite beds as clay seams variously separating and included in beds of halite and sylvinite, as patches in potash ore, and interstitially dispersed between grains of various salts.

Preliminary X-ray diffraction analyses of the insoluble fractions confirm the results of Mossman et al. (1982). Dolomite and quartz tend to be dominant. The clay minerals are mostly illite, chlorite, septechlorite, smectite and mixed-layer clays. Other minerals include K-feldspar, hematite, geothite and anhydrite. A study of the distribution of these minerals in relation to stratigraphic position is in progress, and results will be presented elsewhere.

In the sylvinitic salts, the minerals consist mainly of halite (NaCl) and sylvite (KCl), with variable amounts of insolubles. Only minor carnallite ($KCl \cdot MgCl_2 \cdot 6H_2O$) has been found in the sections examined at Cory Division, although it is common elsewhere (Wardlaw, 1968; Fuzesy, 1983).

The main clay seams in a portion of the Patience Lake Member are shown in Fig. 1. Danyluk (1981)

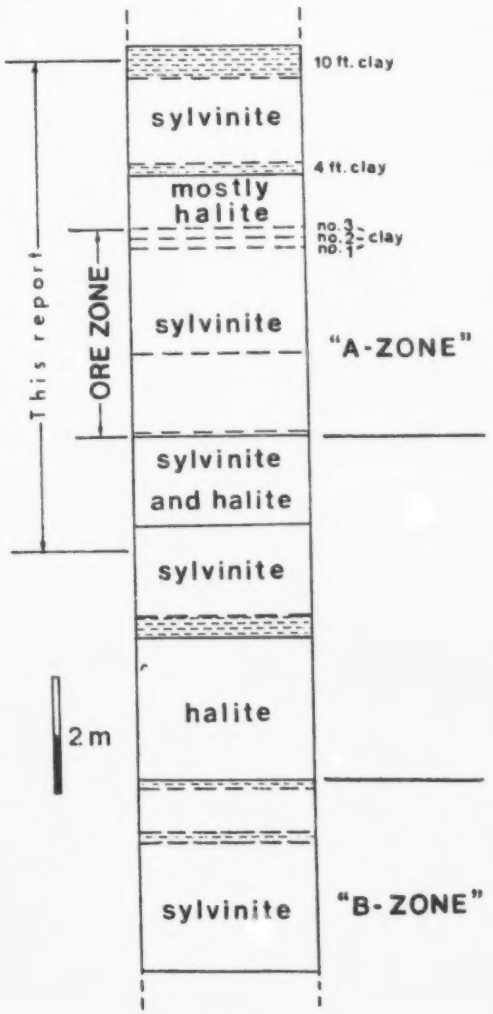


Figure 1 - Generalized stratigraphy of a portion of the Patience Lake Member, PCS Mining Ltd. Cory Division, showing the location of the main clay seams.

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Project funded under the Canada-Saskatchewan Mineral Development Agreement and by PCS Mining Limited.

provided a record of the clay seams in one stratigraphic interval of about 40 m in Cory Division, and the names follow those he assigned. A triplet of clay seams is present at the top of the ore zone. The base of the #1 Clay is commonly used as a datum in the mine. The clay rocks were classified independently of the clay seam stratigraphy.

Most clay seams are continuous, range from 1 to 10 cm in thickness, have fairly abrupt but wavy contacts with adjacent salts, and commonly have massive and/or disseminated clay. The proportion of green, brown, or mottled green and brown clay seams varies widely. Mottled seams may be brown on the inside with green upper and lower contacts or vice versa. Laterally they change abruptly from green to brown, have intermixed green and brown parts or are a mixed light brown to green throughout. The upper and/or lower contacts of most seams may be disseminated or broken up into anastomosing lenses and thin seams (seamlets), and are more massive towards the middle or towards one contact. Fractures are commonly filled with pale fibrous sylvinite 0.2 to 6 mm thick and are thought to be desiccation features. The larger fractures tend to be more common in brown clay seams.

## Methods

In order to evaluate the rock, and compare its appearance to its composition, short core samples were collected from mine wall sections at vertical intervals ranging from less than 5 to about 50 cm using a portable drill. Hand samples were collected in place of and sometimes in addition to core samples. The $K_2O$ content of the water-soluble fraction was analyzed by ion specific electrode and the percentage of insolubles was determined as the

**Table 1 - Proposed Classification of Clay Rocks**

D = disseminated
M = massive
S = sylvite visible

| | | | | |
|---|---|---|---|---|
| The colour is green or greenish grey | | | | |
| Disseminated salts are present | YES | | NO | |
| Sylvite is visible | YES | NO | YES | NO |
| ROCK NAME | Green-DS Clay | Green-D Clay | Green-MS Clay | Green-M Clay |
| The colour is brown | | | | |
| Disseminated salts are present | YES | | NO | |
| Sylvite is visible | YES | NO | YES | NO |
| ROCK NAME | Brown-DS Clay | Brown-D Clay | Brown-MS Clay | Brown-M Clay |
| The colour is mottled green and brown | | | | |
| Disseminated salts are present | YES | | NO | |
| Sylvite is visible | YES | NO | YES | NO |
| ROCK NAME | Mottled-DS Clay | Mottled-D Clay | Mottled-MS Clay | Mottled-M Clay |

Note: if the rock contains patches of one kind in another, the secondary feature may be put in brackets. Eg Brown-D(M) for a disseminated rock with subsidiary massive areas.

weight difference after dissolution of the salts. Representative samples were analysed by X-ray diffraction.

Table 1 was compiled using about 30 samples collected from sections from 3 m above to 2 m below the ore zone (Fig. 1), covering a total stratigraphic thickness of about 8 m.

## Classification

A rock should have more than 15 percent measured insolubles to be classified in this scheme. Three criteria, colour, texture, and the amount of sylvite, were used to classify cores and hand samples. Table 1 shows the classification.

Colour is the most commonly and easily observed criterion. Green is the commonest colour of clay seams in the potash-bearing beds, while brown and mottled brown and green clay tends to be more common in seams associated with halite. Clear beige and brown halite are common in all types of clay seams. Red salt grains are usually sylvite. The difference between the brown and green colour of the clay is presumably due to the oxidation state of the iron.

Texturally there appears to be a continuous variation in the ratio of salts to clay (insolubles). Where the rock appears to be dominantly clay, the texture is called massive; where the insolubles appear to be 40 percent or less, the texture is called disseminated. The appearance is stressed, because analyses indicate that the maximum insolubles are about 40 percent, or about half of what they appear to be. Some seams of disseminated clay are composed of salts with interwoven clays, giving the rock an irregular honeycomb texture. The term 'disseminated' also refers to clay that occurs in the sylvinite and halite beds but in insufficient quantity to be called a clay seam.

Categorizing the texture of a clay seam may be difficult where textures change over short distances (i.e., within a hand sample). In green and brown seams, there is a fairly even split between massive and disseminated textures. In disseminated samples, whether the salts grew during or after clay deposition is as yet unknown.

The presence of visible sylvite (about 5 percent) is considered to be important in using the clay-seam composition as an indicator of anomalous mining ground. Its effectiveness is yet to be established. Sylvite is most common in the green clay seam samples, less common in brown samples, and fairly rare in mixed samples.

## Main Seams

As an example of the use of the proposed terminology, a brief description of the main clay seams is given. The "10 ft." clay seam (Fig. 1) is 4 to 10 cm thick and consists of Brown-D clay containing crystals of colourless halite 2 to 3 cm in size. Between the "10 ft." and "4 ft." clays is an interval that contains several thin seams of mixed Brown-M and Green clay, not shown in Fig. 1.

The "4 ft." clay (Fig. 1) is usually a 10 to 20 cm thick seam of Brown-M (D) clay with Mottled-M (D) or in some places Green-M (D) in the bottom 3 to 4 cm.

The #3 seam is the one used to guide the upper limit for the mining machine and it is therefore close to the back in the mine. In this position it is generally highly strained and difficult to observe in old workings. Furthermore, as Danyluck (1981) points out, it is not easily traced because it is thin, wavy and discontinuous.

The #2 clay (Fig. 1) is usually a single 3 to 4 cm thick seam of Brown-M clay. In one locale it is about 10 cm thick and composed of Mottled-M (D) clay.

The #1 Clay (Fig. 1) consists of a 3 to 4 cm thick basal seam overlain by one or two 1 cm seamlets which may or may not be anastomosing (connecting) with each other and the main seam. This clay is classified as Green-D (M)S clay, with disseminated clay more prominent than massive clay, and with visible sylvite. Clay beds are separated by fine-grained sylvinite 1 to 3 cm thick, which is usually an A or C type potash rock (Langford et al., 1986). Most of the other seams have less sylvite than the #1 Clay.

The Middle clay seam lies approximately in the middle of the ore zone (Fig. 1). It is commonly a Green-DS clay, 2 to 4 cm thick and about 2 m below the base of the #1 seam (datum).

About 3 m below the #1 seam in most areas of the mine, there are one or two clay seams, usually of mottled green and brown clay. Exposure is not very good and hence they have not been well studied.

## Conclusions

Rocks of the clay seams in a potash mine may be subdivided using visual criteria into mappable units. Although variations of the rock types occur, it is hoped that mapping these variations will lead to a better understanding of the stratigraphy and genesis of the evaporites, and the origin of the anomalies. The next phase of this study will be to test this provisional scheme in the Cory Division and other potash mines.

## Acknowledgments

The authors wish to thank the Potash Corporation of Saskatchewan for funding this project. Special

thanks are due to Mr. Don Chipley for assistance with analyses.

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# Summary of Mineral- and Oil-Related Laboratory Research by the Saskatchewan Research Council

by R.G. Arnold[1]

Arnold, R.G. (1986): Summary of mineral- and oil-related laboratory research by the Saskatchewan Research Council, 1986; in Summary of Investigations 1986, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Repor 86-4.

## Uranium Tailings and Processing

Three projects were undertaken on Key Lake and Rabbit Lake tailings as subcontracts to private firms with contracts under the National Uranium Tailing Program. The projects focussed on the mineralogy and chemistry of tailings solids, with emphasis on the fate of radium-226, thorium-230, arsenic and nickel during ore processing. In one project, a hydrous amorphous compound was discovered that was interpreted to contain up to 35 percent nickel and arsenic oxides. This compound is apparently formed during the milling process.

Laboratory and bench-scale work was conducted for a number of uranium producers. The work included crushing, grinding, sampling and analysis of uranium ore samples, in situ leaching experiments, and mine and tailings water disposal studies.

## Rock Mechanics Activities

The design, development, fabrication and installation of stress measurement cells, extensometers and remote data acquisition systems for potash mines is continuing. The purpose of these instruments is to measure and monitor stress and rates of closure underground. Instruments were fabricated for the potash industry in both New Brunswick and Saskatchewan.

SRC is continuing to develop a triaxial testing laboratory with the capability of testing 200 mm (8 inch) diameter by 800 mm (16 inch) long cores. These test cells are currently the largest in Canada. A project is underway in cooperation with Cominco's potash mine to integrate the creep behaviour of potash under triaxial test conditions, mathematical modelling of creep and underground in situ measurements. The project is financially supported by Energy, Mines and Resources Canada.

Modification of one or more triaxial cells is being considered to permit the measurement of permeability in unconsolidated or soft rocks under triaxial stress conditions. This capability would permit studies of fluid flow in porous media in large samples under simulated burial conditions.

## Slurry Pipeline Studies

Recent projects by SRC's slurry pipeline group have focussed on the pipelining of mine tailings for the design of tailings transport systems and for the development of computer models of flow regimes in pipelines. Oil-in-water emulsion studies are being investigated as an option for the transport of Saskatchewan heavy crude oil in pipelines.

## Petroleum Research

In June 1985, the Saskatchewan Research Council acquired the Heavy Oil Laboratory in Regina which was formerly a part of Saskoil. Division activities focus mainly on heavy oil. Projects range from enhanced oil recovery to production, treatment and upgrading. Enhanced recovery of light and medium oil is also being pursued. The purpose of the Division is to use its research capability to help the Saskatchewan oil industry solve some of its most pressing technical problems.

Enhanced heavy oil recovery projects are underway in the areas of steam injection, in situ combustion and immiscible $CO_2$ flooding. A light and medium oil enhanced recovery project focusses on miscible flooding with $CO_2$ and hydrocarbon gases.

Production problems are being addressed with projects on sand control and emulsion treatment. Heavy oil upgrading is being studied with particular emphasis on determining the upgrading characteristics of enhanced recovery feedstocks and on methods to overcome the problems associated with upgrading these feedstocks.

[1]Saskatchewan Research Council, Saskatoon.

## Abstracts of Recent Saskatchewan Energy and Mines Publications

Fuzesy, M.A. (1986): Assessment work catalogue, Reindeer Mining District; Saskatchewan Energy and Mines, Miscellaneous Report 86-5, 80p.

Fuzesy, M.A. (1986): La Ronge assessment work catalogue; Saskatchewan Energy and Mines, Miscellaneous Report 85-5, 132p. (supplement to Miscellaneous Report 79-4, repreinted with addenda and revised confidentiality status).

Harper, C.T. and Thomas, D.J. (1986): Geological setting of gold mineralization in the Star-Waddy Lakes area, Saskatchewan; abstract presented to Gold '86, An International Symposium on the Geology of Gold Deposits; Toronto; September 28 to October 1, 1986.

The Star-Waddy Lakes area lies within the northeasterly-trending early- to mid-Proterozoic volcanosedimentary-plutonic belt referred to as the La Ronge Domain. In the area investigated, the domain is composed of the Central Metavolcanic Belt bordered by metasedimentary belts, known as the Crew Lake and MacLean Lake Belts, to the northwest and southeast respectively. The boundaries between these belts and the Central Metavolcanic Belt are generally marked by prominent zones of shearing.

In the Star-Waddy Lakes area the Central Metavolcanic Belt comprises ultramafic to felsic metavolcanic, metavolcaniclastic, and minor intercalated metasedimentary assemblages. The heterogeneity of volcanic rock types exposed along the belt indicates that different structural, and therefore, stratigraphic levels through the volcanic pile are preserved at the present erosional surface. There appears to be a general deepening, from the northeast to southwest, of the structural/stratigraphic level of the belt, such that the dominantly mafic character of the metavolcanics of the Star-Roundish-Bervin Lakes region would represent a lower level than the area around Waddy Lake where an extensive accumulation of felsic metavolcanic rocks are preserved. Locally, some of the felsic metavolcanics are associated with the deposition of iron formation, typically of sulphide facies. Geological and geochemical evidence indicates that the Central Metavolcanic Belt evolved in an island arc environment. The metavolcanic rocks have a dominantly calc-alkaline to mildly tholeiitic character. However, some rocks from the south end of Waddy Lake display komatiitic to basaltic-komatiitic affinities. U-Pb zircon ages indicate that volcanism occurred about 1875 Ma ago.

The volcanosedimentary succession is intruded by a variety of ultramafic to felsic plutons, which, on the basis of lithology, field relations, and geochronology, can be broadly subdivided into three groups. These are: a) an 'early' (ca. 1865 Ma), possibly subvolcanic, episode marked by composite intrusions ranging from gabbro-diorite to granite; b) an 'intermediate' (ca. 1854 Ma) plutonic event distinguished by more homogeneous felsic intrusions; and c) a 'later' (ca. 1835 Ma) event characterized by leucocratic quartz-rich granite intrusions. The plutons, which have chemcial properties typical of island arc granites, are also largely calc-alkaline in character and shown little variation from the volcanics.

The La Ronge Domain has undergone polyphase deformation with a strongly developed northeast-trending structural grain. Large scale folding within the study area is manifested by large regional synforms, arcuate and triangular patterns associated with many of the plutons and by tight to isoclinal folds within the adjacent metasedimentary belts. Much of the Star-Waddy Lakes area is characterized by inhomogeneous strain. Very steep strain gradients are typical, such that zones of high strain, consisting of extreme extensional fabrics, discrete shearing, as well as broader zones of cataclasis, are often juxtaposed with areas of relatively minimal deformation. Dilation structures tend to favour these zones of highly contrasting strain. Late brittle fractures, faults and shear zones are widespread and appear to be particularly important as loci for gold mineralization.

Large iron sulphide-bearing zones were known from as early as 1928 in the vicinity of Lower Nistoassini Lake, Kirk and Hump Lakes and Forbes Lake. These zones have been re-examined many times for base metal, gold and iron potential. In the mid to late 1940's prospectors discovered several significant gold occurrences in the Star-Waddy Lakes area, but by the mid-fifties interest in these had declined. The La Ronge Domain has seen a resurgence of gold exploration activity in recent years which has led to several significant new gold occurrences being discovered, notably the 21, Rod, Blindman, EP and Twin Zones.

The majority of gold occurrences in the Star-Waddy Lakes area are structurally controlled vein-type whereas stratiform-type are rare. The most persistent features of the vein-type occurrences are:

1. A closer association with intrusive rocks, most commonly of intermediate to felsic composition; mineralization occurs both internally and externally to the intrusions. Type 1 (composite, zoned plutons, e.g. Star Lake, Brindson Lake, and Nistoassini Lakes Plutons) and Type 3 (leucocratic granite stocks, e.g., Round Lake, Kidney Lake, and Windrum Lake Stocks) intrusions have associated gold mineralization. Type 2 (homogeneous granitic plutons) intrusions have thus far not been found to have associated gold mineralization; however, they should not as yet be ruled out as prospective targets.

2. Structural control in the form of shear zones accompanied by the development of fracture systems or dilation zones in respect to the shearing. In the Star Lake vicinity, structures trending 060° and 030°, as well as their intersections, are important (e.g. 21, Kahn 18, Blindman Lake, Rush Lake, Rod and Jolu). In the Tower-Waddy Lakes region structures that are broadly north-south (e.g. Partington Lake), east-west (Narrow Lake, Tower Lake, Oven Lake) and northeast-trending (e.g. Komis, Weedy B) are mineralized. Many of the gold occurrences in the latter region are closely associated with the generally east-west trending Byers Fault, which crosses that region.

3. Emplacement of sulphide-bearing quartz veins within the fracture systems. Associated wall rock alteration, which is commonly of very limited extent, is characterized by silicification, and the development of chlorite, pyrite, and less commonly carbonate, epidote, hematite, muscovite, and tourmaline. Gold typically occurs in the native form in close association with pyrite in both the quartz veins and adjacent wall rocks. The mineralized quartz veins may also contain pyrrhotite, chalcopyrite, sphalerite, galena, molybdenite, tourmaline, or scheelite.

4. Non-intrusive gold-bearing host rocks are preferentially mafic to intermediate metavolcanics, less commonly felsic metavolcanics, and rarely metasedimentary rocks.

5. Xenoliths, roof pendants and dykes of mafic to felsic material are associated with some occurrences but their genetic relation to mineralization is not yet clear.

The vein-type gold occurrences appear to have formed by both magmatic hydrothermal and metamorphic hydrothermal processes. An important feature to note is that gold occurrences can form internally and externally to intrusive rocks by either process.

Stratiform or syngenetic gold occurrences are presently known in the Waddy Lake region (e.g. Twin Zone). Bedded and massive sulphide-facies iron formations have so far only yielded trace concentrations of gold; however, where base metal concentrations are elevated, as at the Churchill Minerals and Early Lake occurrences, so is gold. A mixed oxide-silicate-sulphide-carbonate facies iron formation with sporadic disseminated arsenopyrite at the Twin Zone represents the most significant syngenetic gold occurrence found to date. Other possible syngenetic occurrences are suggested by elevated gold concentrations (e.g. 20 to 100 ppb) in pyritic felsic tuff horizons in the Waddy Lake region.

Harper, C.T., Taylor, R.P. and Fryer, B.J. (1986): Geology and Lithogeochemistry of the Maurice Bay uranium deposit of the Maurice Bay urainum deposit, northern Saskatchewan; in Uranium Deposits of Canada, CIM Special Volume 33.

The Maurice Bay deposit is one of a number of uranium deposits that have been found in recent years in the Athabasca Basin of northern Saskatchewan (Tremblay, 1982). This deposit, along with the others, belongs to the unconformity type deposits (Beck, 1977). They are, for the most part, polymetallic, being characterized by a suite of metals which include U, Ni, Co, Cu, Pb, Zn, Mn, V, Ag, Au, Pt-group elements, S, As, Bi, Se, Te, and Mo, some of which, beside U, are present in economic concentrations (Amok, 1974; Ruzicka, 1975; Tapaninen, 1976; Hoeve and Sibbald, 1978; Dahlkamp, 1978). The Maurice Bay deposit was known to be a small low grade deposit in which the ore was essentially monomineralic, consisting mainly of pitchblende (Harper, 1978). However, the occurrence of trace amounts of some of the elements common in the larger polymetallic orebodies (e.g. Key Lake, Cluff Lake D) was anticipated. Thus a lithogeochemical sampling project was undertaken in 1979 across part of the Maurice Bay deposit (Harper, 1979). Major oxides ($SiO_2$, $Al_2O_3$, FeO, $Fe_2O_3$, MgO, CaO, $K_2O$, $Na_2O$, MnO, $P_2O_5$, and $TiO_2$) and a group of the most common trace metals (U, Ni, Co, Cu, Pb, As, Au, V, and Se) were analyzed to determine whether any elemental patterns (halos or depletions) could be detected which would reduce the number of pathfinder elements needed for exploration purposes. In addition to the above metals, Th was also checked because some conglomerative strata in the Maurice Bay area are know to be thorium-enriched (Harper, 1978). Only the trace metal distributions will be discussed in detail in this report.

Harper, C.T., Thomas, D.J., and Watters, B. (in press): Geology and petrochemistry of the Star-Waddy Lakes Area, Saskatchewan; in Gold in the Western Shield; CIM Geology Division Gold Symposim and Field Tours.

The Star-Waddy Lake area lies within the northeasterly-trending early- to mid-Proterozoic volcanosedimentary-plutonic belt referred to as the La Ronge Domain. In the area investigated the domain is composed of the Central Metavolcanic Belt which is bordered by metasedimentary belts of the Crew Lake and MacLean Lake Belts to the northwest and southeast respectively. The boundaries between the Central Metavolcanic Belt and the flanking belts are generally marked by prominent zones of shearing. The volcanosedimentary succession is intruded by a variety of ultramafic to felsic plutons which, on the basis of lithology, field relations and geochronology, can be broadly subdivided into three groups of episodes. These are: a) an 'early' (ca. 1866 Ma), possibly subvolcanic, episode marked by composite intrusions ranging from

gabbro-diorite to granite, b) an 'intermediate' (ca. 1854 Ma) plutonic event distinguished by more homogeneous felsic intrusions; and c) a 'later' (ca. 1835 Ma) event characterized by leucocratic quartz-rich granite intrusions.

The La Ronge Domain has undergone polyphase deformation with a strongly developed northeast-trending structural grain. Large scale folding is manifested by large regional synforms, arcuate and triangular patterns associated with many of the plutons and by tight to isoclinal folds within the adjacent metasedimentary belts. Inhomogeneous strain characterizes much of the Star-Waddy Lakes area. With strain gradients being typically very steep, zones of high strain consisting of zones of extreme extensional fabrics, discrete shearing, as well as broader zones of cataclasis and structural slicing, are often juxtaposed with areas of relatively minimal deformation. Dilation structures tend to favour these zones of highly contrasting strain. Late, brittle fractures, faults and shear zones are widespread and appear to be particularly important as loci for gold mineralization. Metamorphic mineral assemblages indicate that upper greenschist to middle amphibolite facies conditions were attained.

Geological and geochemical evidence indicates that the Central Metavolcanic Belt evolved in an island arc environment. Metavolcanic rocks from both the Waddy and Star Lakes areas display similar characteristics on variation diagrams (e.g. AFM and the Jensen cation plot) in that the dominant trend is calc-alkaline with some basic to intermediate types having a mildly tholeiitic character. A few samples from the southern end of Lower Waddy Lake display komatiitic to basaltic-komatiitic affinities.

The relatively immobile minor and trace elements (e.g. Ti, Zr, Nb, Y, Cr) provide reliable characterization of the metavolcanics, particularly of the basalts, which have highly distinctive trace element properties. Geochemical patterns for the basalts are similar to those for modern volcanic arc basalts. Low initial $^{87}Sr/^{86}Sr$ ratios (0.7017 - 0.7019) are consistent with a subduction-related origin for the volcanics.

The major plutons have chemical properties typical of volcanic arc granites and are largely calc-alkaline in character, showing little chemical variation from the volcanics.

The majority of gold occurrences in the Star-Waddy Lakes area are structurally-controlled deposits. Stratiform-type gold occurrences are a minor variety.

Parslow, G.R. and Gaskarth, J.W. (1986): Geochemistry of the Hanson Lake Area, Saskatchewan, Canada; Saskatchewan Energy and Mines, Open File Report 86-1, 122p.

Parslow, G.R., Gaskarth, J.W. and Zhang, J-L. (1986): Geochemistry of the Annabel Lake area; Saskatchewan Energy and Mines, Open File Report 86-3 154p.

Parslow, G.R, Brandstatter, F., Kurat, G. and Thomas, D.J. (1985): Chemical ages and mobility of U and Th in anatectites of the Cree Lake Zone, Saskatchewan; Canadian Mineralogist, v23, p543-551.

Microprobe analyses have been carried out, and chemical ages determined, on the radioactive phases in anatectites from five localities in the Cree Lake zone (Saskatchewan). In addition, bulk analyses for U, Th and Pb were completed on over 150 samples of the anatecites and their host rocks. Exclusive of zircon and monazite, the U- and Th-bearing phases range from old "uraninite" through various unnamed U-Th silicates to young "uranophane", "coffinite" and "kasolite". Only one rare phase, a U-Fe silicate, was encountered; the only known analog occurs in Styria (Austria). Chemical ages range from 1.9 to <0.1 Ga and bulk values from 23 to 413 ppm U, 10 to 285 ppm Th and 26 to 144 ppm Pb. Both the petrographic data and the inferred ages indicate that extensive mobilization of the radioactive phases has occurred, either continuously or episodically. The mobility, however, was restricted to the interior of the anatectite bodies, which behaved essentially as closed systems. The oldest chemical ages are in close agreement with geological estimates of the timing of anatectite formation.

Salt,D.P,. (1986): Annotated bibliography of Saskatchewan geology theses; Saskatchewan Energy and Mines, Data File 10, 105p.

Scott, B.P. (1986): Geology of the Phelps Lake (southwest) area; Saskatchewan Energy and Mines, Open File Report 86-2, 12p.

Supracrustal units of felsic gneiss, hornblende gneiss, diopside gneiss and biotite gneiss were isoclinally folded about east-west axes ($F_1$). Later folding about north-trending axes ($F_2$) was accompanied by granodiorite intrusion.

Medium- to high-grade metamorphism is indicatd by the presence of cordierite, sillimanite and hypersthene.

Subeconomic traces of several rare earth elements have been reported in megacrystic granite at Nordbye Lake.

Suryam, J.V. (1986): Seismic map SM-1, Souris River area, southeastern Saskatchewan; Saskatchewan Energy and Mines, scale 1:126,720 (1 inch to 2 miles).

This compilation seismic map of the structure on the top of the Paleozoic unconformity surface covers an area between Townships 1 and 8 and Ranges 30W1 and 14W2. It is based on the original seismic data submitted to the department by oil companies under the Petroleum and Natural Gas Permit Regulations. The original data has now attained a non-confidential status. Locations and the status of the oil and gas wells drilled in the area are also provided, along with an explanatory note.

Thomas, D.J. (1985): Geology of an area around Star Lake; Saskatchewan Energy and Mines, Open File Report 85-6, 83p.

The area is underlain by Precambrian rocks of the Central Metavolcanic Belt, Crew Lake Belt and McLennan Group, which together form part of the larger La Ronge Lithostructural domain.

The Central Metavolcanic Belt portion of the Star Lake area is composed largely of metavolcanic units that grade laterally into volcanogenic and epiclastic metasedimentary rocks of the Crew Lake Belt to the west. Along the southeastern margin of the Central Metavolcanic Belt, feldspathic meta-arenites and metaconglomerates of the McLennan Group structurally underlie the metavolcanics. The metavolcanic assemblage of the Star Lake area is characterized by a substantial thickness of basic to intermediate, submarine to subaerial pyroclastic deposits, which increasingly give way to more flows and less pyroclastics southwards. Felsic metavolcanics make up less than 5 percent of the volcanosedimentary succession.

The volcanosedimentary complex has been intruded by a spectrum of relatively simple to complex, basic to acid bodies. Field relations suggest an 'early', possibly subvolcanic episode marked by composite intrusions ranging from gabbro-diorite to granite, as well as by the emplacement of many of the ultrabasic to basic intrusions. A 'later' plutonic event is distinguished by more homogeneous uniform acid intrustions.

Metavolcanic rocks of the Star Lake area have a dominant calc-alkaline geochemical trend, although a continuum from low potassium tholeiite through to calc-alkaline exits. The calc-alkaline rocks are typically high in Al and the suite as a whole is low in Ti. The geochemical evidence indicates volcanic rocks of the Star Lake area were emplaced in an island arc environment.

Major fold closures are not recognized in the Star Lake metavolcanic sequence, although tight to isoclinal folds with northeast-trending axial surfaces are common in metasedimentary units west of the metavolcanics.

Inhomogeneous strain characterizes much of the Star Lake area in the form of zones of extreme extensional fabrics, discrete shearing, and broader zones of cataclasis and structural slicing. Strain gradients are typically very steep throughout the area. Dilation structures tend to favour these zones of highly contrasting strain. Two northeast-trending belts of intensely deformed rocks occur in the area, one extending through the Alpat Lake area (Alpat Lake Tectonic Zone) and the other along the west side of McLennan Lake (McLennan Lake Tectonic Zone). Late brittle fracturing, faulting and shearing are widespread. Metamorphic data from the Star Lake area indicate that upper greenschist to lower amphibolite facies conditions were attained in the La Ronge Domain, while at least middle amphibolite facies conditions were reached in rocks of the McLennan Group.

Gold-quartz vein mineralization appears to be related to dilation structures developed in shear zones within or along the margin of the Star Lake Pluton. The most important occurrences are the '21' zone, 'Pie' zone, Tamar showing and Jolu property. In addition to gold mineralization, several occurrences of pyrrhotite and chalcopyrite-pyrrhotite are present in the Star Lake area, notably in metagabbros at Neyrinck Lake and pelitic metasediments west of Alpat Lake.

Thomas, D.J. (1985): Saskatchewan metallic mineral exploration update; paper presented at 91st Annual Northwest Mining Association Convention, Spokane, Washington, December 6, 1985.

Thomas, D.J. (1986): Volcanic rocks, intrusions and gold mineralization, Star-Waddy Lakes area, northern Saskatchewan, or "The anatomy of the La Ronge Gold Belt"; paper presented to Edmonton Branch, Canadian Institute of Mining and Metallurgy; Edmonton, April 3, 1986.

The Star-Waddy lakes area is located in the Central Metavolcanic Belt of the La Ronge Domain in northern Saskatchewan. This domain is one part of the Lower Proterozoic "Trans-Hudson Orogen" and comprises of a collage of metavolcanic-plutonic arc assemblages, thick flysch-type metasedimentary sequences and large intrusive complexes. The Central Metavolcanic Belt forms a northeasterly-trending belt of predominantly metamorphosed calc-alkaline basaltic to rhyolitic flow, pyroclastic and intravolcanic sedimentary units. Submarine to subaerial environments are inferred in the volcanic sequence and cyclic basic to acid volcanism is locally present. The volcanosedimentary succession is intruded by a variety of uniform to multiphase, ultramafic and mafic to felsic bodies ranging from synvolcanic to posttectonic in emplacement. Bounding

structural zones, incorporating protomylonitic to mylonitic rocks, separate the Central Metavolcanic Belt from thick metasedimentary sequences to the east and west.

Gold mineralization in the Star-Waddy Lakes area has been known since the 1930's. With the resurgence of gold exploration activity during recent years, interest in the "La Ronge Gold Belt" has been high. Gold mineralization in the Star-Waddy Lakes area is primarily shear zone controlled vein-type, formed through metamorphic-hydrothermal processes. Stratabound gold mineralization is also present, although less common, and is typically associated with iron-rich metasediments, suggesting an exhalative stratiform magmatic-hydrothermal origin. Recent gold exploration has led to the discovery of several significant new deposits, particularly in the Star Lake area. Construction of a mine-mill complex is in progress at the Star Lake 21 zone deposit, with production planned for the spring of 1987.

This presentation will review the geological setting of the Star-Waddy Lakes area and its associated gold mineralization. Three main features will be discussed:

1) the general character of the volcanic succession and its implications regarding the geotectonic setting;

2) the character of felsic plutons in the belt, particularly in view of the significant gold mineralization associated with several intrusions;

3) a brief review of gold mineralization, illustrated with examples from the Star Lake 21-Zone, Waddy Lake Komis deposit and Wedge Lake Twin zones.

Van Schmus, W.R., Bickford, M.E., Lewry, J.F. and Macdonald, R. (in press): U-Pb Geochronology in the Trans-Hudson Orogen, Northern Saskatchewan; Can. J. Earth Sci.

We have obtained U-Pb ages on zircons from volcanic and plutonic units in several lithotectonic domains of the southern Trans-Hudson Orogen in northern Saskatchewan. These data constrain the timing of early Proterozoic orogenic events in the region and enhance our understanding of both the relationships among local domains and the relationship of the Trans-Hudson Orogen to other early Proterozoic orogens in North America.

With one exception, all units studied so far yield zircon ages of 1890 to 1835 Ma and indicate that most zircon ages are systematically older than previously reported Rb-Sr isochron ages on the same or similar units, suggesting open-system behavior in the Rb-Sr systems. Five metarhyolites, from volcanic sequences in the La Ronge Domain, Glennie Domain, and Hanson Lake Block, give ages ranging from 1888 to 1876 Ma. Most of the plutons we have dated, ranging from gneissic syntectonic tonalites and granodiorites to less deformed late intrusions such as the Wathaman Batholith and other smaller bodies, yield ages of 1870 to 1850 Ma, apparently constraining peak plutonic activity to about 1860$\pm$ 10 Ma ago. The youngest unit found is a small discordant pluton with an age of 1836 $\pm$ 7 Ma. The concordance of ages of volcanics on the one hand and plutons on the other suggest that domainal distinctions are mainly lithotectonic rather than temporal.

Zircons from the Sahli charnockitic granite in the Hanson Lake Block yield equivocal results. Discordia upper and lower intercepts for the Sahli granite suggest that granitic rocks at least 2500 Ma old were subjected to high-grade metamorphism about 1800 to 1900 Ma ago, with substantial resetting of zircons. Reworked Archean basement is thus present in this domain, supporting previously reported Rb-Sr isochron data from the Sahli granite. No other indications of Archean basement in the Trans-Hudson Orogen are documented, although one sample from the adjacent Peter Lake Domain shows that it consists of Archean continental crust.

Zircon ages in the range 1890 to 1835 Ma from this part of the Trans-Hudson Orogen are closely similar to those obtained from igneous units of the Penokean and Wopmay Orogens, in North America, and from the Svecofennian Orogen, suggesting essential synchroneity of igneous and tectonic events in these four major orogens during major early Proterozoic continental assembly.

The following report is being published by the Saskatchewan Research Council with approval of funds provided by the Saskatchewan Geological Survey:

Schreiner, B.T. (1986): Quaternary geology as a guide to mineral exploration in the southeastern shield, Saskatchewan; Saskatchewan Energy and Mines, Open File Report 86-5 (also published as Saskatchewan Research Council, Report R-UV-86).

A review is given of what is known of the Quaternary geology in the area and its application to drift prospecting for minerals, particularly gold. Gaps in knowledge are identified and investigations are suggested to fill these gaps in information. The area covered is the Central Metavolcanic Belt of the La Ronge Domain and the region to the southeast, extending eastward to the Manitoba border and southward to the edge of the Shield.

A review is included of existing information on the Quaternary geology and geochemistry. The Quaternary geological setting and stratigraphy are described in order to provide a framework and guideline for effective drift prospecting. The common lithological units are described, particularly the till deposits, which are characterized geochemically. Typical soil profiles are described from various sites, lithological materials and topographic situations. Typical sections from exposures of drillholes are presented to establish the stratigraphy of the drift deposits. Generalized maps show the areal distribution, assumed thickness and topographic expression of the deposits.

Examples of explained and unexplained drift prospecting anomalies such as boulder trains and till dispersal fans are included as typical cases. An attempt is made to relate the distribution of gold in the Quaternary deposits to gold deposits in bedrock.

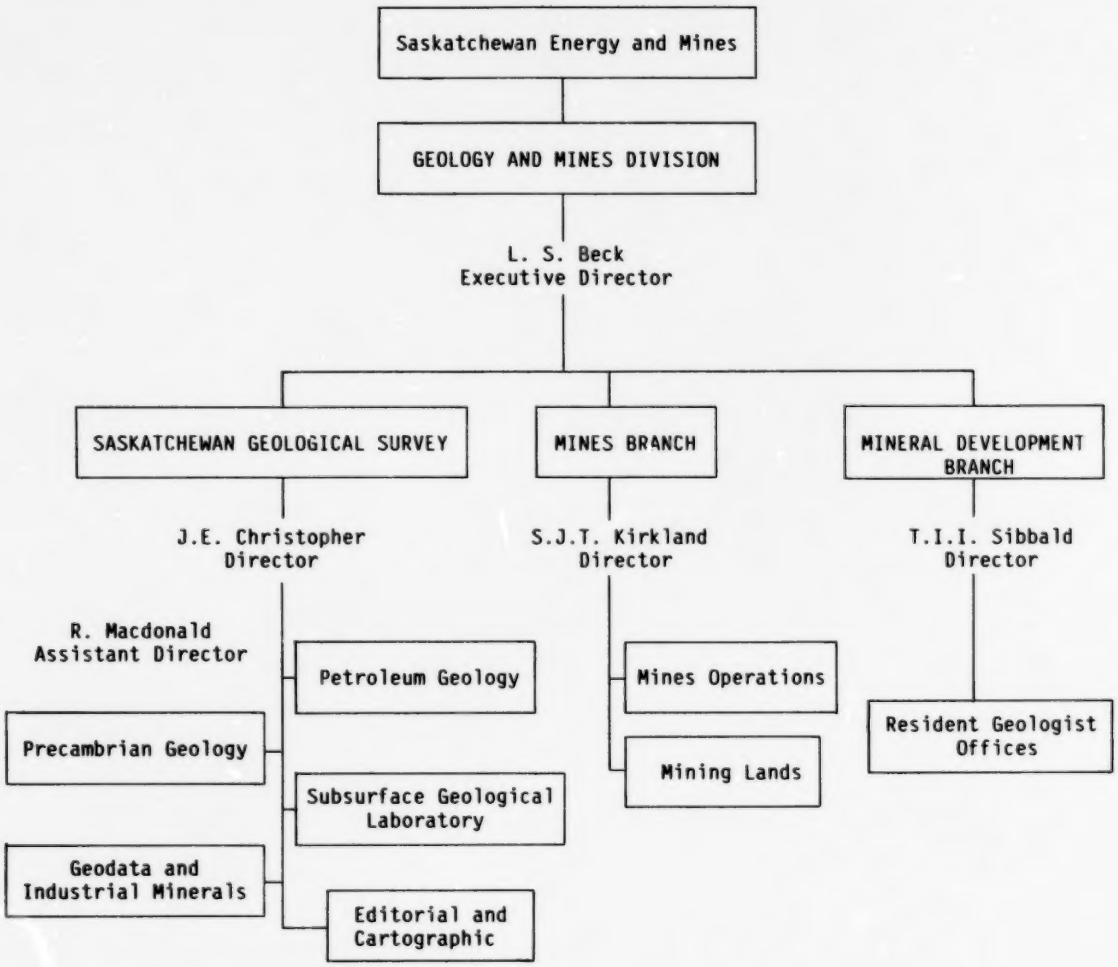
The report includes a review and discussion of the problems of interpretation experienced by explorationists attempting to use Quaternary deposits for mineral exploration in the Saskatchewan gold belt. Recommendations are also included for future investigations aimed at improving the effectiveness of drift prospecting in this area of gold potential.

The author is a research scientist with the Resources Division of the Saskatchewan Research Council, Saskatoon. The project was contracted to the Saskatchewan Research Council with funds provided under the Saskatchewan component of the Canada-Saskatchewan Subsidiary Agreement on Mineral Development 1984-89.

**Acknowledgments**

Senior assistants who assisted project leaders in the field are named on the accompanying maps. Full acknowledgment for assistance in the field is expected to be made in the final reports, where applicable.

The editors are grateful for assistance given in the editing and production process by Jim Christopher, Anne Fuzesy, Blaine Scott, Bill Slimmon, Dave Thomas and Gary Delaney and Paul Saganski. Word-processing of the report was handled by Jagdish Bilkhu, with assistance from Betty Tremblay, Vivian Barkman, Cheryl Resener and Louise Lake. Pat Kydd, Ken Jones and Phil Weir handled preparation of some of the figures and, with assistance from Jim Bedo, Rick Pearce, Keith Poitras, Harry Buyze and Ed Sloat, assembled the manuscript maps.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